Energy Research and Development Division
FINAL PROJECT REPORT

BUILDING COMMISSIONING: STRATEGIES AND TECHNOLOGIES FOR ENERGY EFFICIENCY

Prepared for: California Energy Commission
Prepared by: The California Commissioning Collaborative

JUNE 2013
CEC-500-2013-012

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Contract Number: 500-08-039

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ACKNOWLEDGEMENTS

The California Commissioning Collaborative (CCC) owes gratitude to a wide array of participants and trusted advisors who contributed to the success of the program **Building Commissioning: Strategies and Technologies for Energy Efficiency.** The research and development under this program were led by Portland Energy Conservation, Inc. , Architectural Energy Corporation (AEC), Quantum Energy Services and Technologies (QuEST), and Enovity. Additional support was provided by Eaton, EnerNOC, and Heschong Mahone Group. Specific program and project roles were defined as follows:

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- **Principal Investigator:** Defines technical requirements for deliverables, approves deliverables prior to submission to the Energy Commission. Technical task Principal Investigators were:
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- **Technical Director:** Hannah Friedman Kramer (CCC)
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Voluntary Technical Advisory Groups provided input on direction of tasks and took time to provide thoughtful review of deliverables. The California Commissioning Collaborative's Advisory Council performed the role of the Program Advisory Committee, helping to strengthen connections between each of the tasks and enabling connections to the market.

The California Commissioning Collaborative is grateful to the many building owners, managers, commissioning providers, contractors, and vendors who participated in interviews and pilots and provided material for case studies.

PREFACE

The California Energy Commission Energy Research and Development Division supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The Energy Research and Development Division conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

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- Energy Innovations Small Grants
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- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies
- Transportation

Building Commissioning: Strategies and Technologies for Energy Efficiency is the final report for the Building Commissioning: Strategies and Technologies for Energy Efficiency program (contract number 500-08-039) conducted by the California Commissioning Collaborative. The information from this program contributes to Energy Research and Development Division's Buildings End-Use Energy Efficiency Program.

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ABSTRACT

Existing building commissioning is a systematic process for investigating, analyzing, and optimizing the performance of building systems. Research on projects across the United States has indicated median energy savings of 16 percent for existing building commissioning projects, along with indirect benefits such as improved occupant comfort and reduced maintenance costs. In spite of the proven benefits, existing building commissioning has not achieved high market penetration. Several market barriers have been identified, including a lack of understanding of the process and its benefits by building owners, and a lack of standardized tools for implementing the process.

The 2009-2012 research and development program Building Commissioning: Strategies and Technologies for Energy Efficiency, managed by the California Commissioning Collaborative, resulted in new research and tools that can help address market barriers to greater penetration of existing building commissioning. This integrated program engaged seven firms and more than 90 expert advisors in developing and promoting a range of resources that have been made freely available for public use.

The research team's interviews with industry stakeholders, site visits, and literature review confirmed the market need for guidance to support existing building commissioning projects. The research also indicated a lack of data on related topics such as persistence of energy savings, compliance rates for building code requirements, and the connection between energy performance and property value.

The tools, guidelines, and document templates developed under this program were promoted through a combination of presentations, articles, and direct outreach to influential industry organizations. The research team's recommended next steps include integration of the new tools and other related practices into California's programs at the utility and state level. In parallel, efforts may be taken towards market transformation by engaging with industry stakeholders to develop the infrastructure and market demand for existing building commissioning outside of formal programs.

Keywords: Public Interest Energy Research program, PIER, California Commissioning Collaborative, CCC, existing building commissioning, EBCx, retrocommissioning, RCx, energy, energy efficiency, energy conservation, California building owners, commissioning provider, commissioning resources, commissioning tools, RCx Toolkit, data analysis tools, energy savings calculation tools, utility programs, persistence, monitoring, energy information systems, EIS, FDD, ECAM , C-BOA, Title 24, commercial real estate, due diligence

Please use the following citation for this report:

Crowe, Eliot. (California Commissioning Collaborative). 2013. ***Building Commissioning: Strategies and Technologies for Energy Efficiency***. California Energy Commission. Publication Number: CEC-500-2013-012.

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EXECUTIVE SUMMARY

This report summarizes the integrated research and development program *Building Commissioning: Strategies and Technologies for Energy Efficiency*, which was funded by the California Energy Commission's Public Interest Energy Research Program**.** This 2009-2012 program, managed by the California Commissioning Collaborative (CCC), saw the development of a suite of new tools and guidelines designed to address technical and market barriers that will result in greater adoption of existing building commissioning.

Background

Existing building commissioning improves the energy performance of buildings by ensuring that systems and equipment operate as designed and that building facility staff are able to operate and maintain them effectively. Research on past existing building commissioning projects has shown median project savings of 16 percent, with a simple payback of 1.1 years, a relatively high rate of return when compared with equipment retrofit projects. However, the technical complexity and lack of market understanding of the existing building commissioning process, benefits, and outcomes create challenges that hinder widespread implementation of the practice and reduce the realization of energy savings.

The *California Energy Efficiency Strategic Plan*, developed by the California Public Utilities Commission, identified commissioning under Strategy 2-5, for the Commercial Sector: "Develop tools and strategies to use information and behavioral strategies, commissioning, and training to reduce energy consumption in commercial buildings." Under this general strategy, the strategic plan highlighted the need to "strengthen tools and practices for building commissioning." This research program has directly contributed to addressing this need.

Some elements of the *Building Commissioning: Strategies and Technologies for Energy Efficiency* research program are direct implementation of recommendations from the 2006-2008 program, *Commercial Commissioning Research and Development*. The 2006-2008 program resulted in market research, development of the CCC's existing building commissioning toolkit, and supported development of a guideline for verifying savings from existing building commissioning projects.

Purpose

The purpose of this integrated research program was to address market and technical barriers that hinder widespread implementation of the commissioning practice to deliver energy savings in California buildings. The overall goals of this program were to:

- Simplify decision-making by providing building owners with actionable energy information that will put them on the path to implementing commissioning in their properties.
- Strengthen commissioning practices by developing standardized tools and processes for providers, owners, and other industry stakeholders to enable more cost-effective

implementation of existing building commissioning and long-term persistence of benefits.
- Quantify the savings from existing building commissioning by developing guidance for the selection and implementation of energy savings verification methods that are appropriate for existing building commissioning projects.
- Increase building efficiency achieved by supporting the California Energy Commission in improving the technical feasibility of and compliance with acceptance testing requirements in California's building efficiency code (Title 24, Part 6).

To address this broad set of goals, the research program comprised five separate but related technical tasks, in addition to a program administration task. Each of the technical tasks is described in full in Chapters 2 through 6.

Research and Development Approach

The CCC engaged a team of seven firms with a range of specialties to perform work under this program. A research program manager, a technical director, and a CCC program manager oversaw the program. A principal investigator and a project manager were allocated to each technical task, directing the work of the task research teams. More than 90 industry experts provided additional support through voluntary technical advisory groups and a program advisory committee.

Among the five technical tasks under this program, there were varying degrees of research (primary and secondary) and development. Throughout the program, the CCC maintained a firm commitment that the tools and guidelines developed should provide maximum value to the target audience: commissioning providers, program implementers, building owners, and property managers. While the research provided many useful insights for the commissioning industry, the primary purpose of this program was to leverage that research through the development of effective new tools and guidelines.

Research and Development Outcomes

The five tasks under this program resulted in a significant increase in the resources available through the CCC's commissioning toolkit, all of which are available for free download. The CCC's website, http://www.cacx.org/resources/rcxtools/ receives 23,000 visitors annually, and announcements were mailed to more than 1,200 subscribers. Tools and guidelines were built on the latest research and the expertise of experienced practitioners. The outcomes from each technical task are summarized below.

Improving Integration of Energy Information and Existing Building Commissioning (EBCx) Services in Commercial Real Estate Transactions

The overall goal of this task was to pilot and deploy a technical and market approach toward improving the transparency of a building's energy performance at time of sale, and to increase the capacity of property condition assessment firms to provide energy assessment services. The research team examined current practices for property due diligence through primary and secondary research, identifying the process steps, the stakeholders, decision makers, and the

priorities of those decision-makers. This research task looked beyond energy benchmarking at time of sale to assess operational improvement opportunities.

Building on the secondary research and interviews with 11 industry stakeholders, the research team conducted six pilot projects designed to assess and refine an operational assessment approach. The pilot projects were used to evaluate the relative costs, benefits, and applicability of an existing building commissioning high-level screening in comparison with a more detailed scoping. The assessment process was refined through the course of the pilot projects based on feedback on the practicality of the site walkthrough, the value of the reporting, and the required skill level for performing the assessment. Once the pilot projects were complete, the research team interviewed eight industry stakeholders to obtain feedback on the final recommended assessment approach.

The primary deliverable under this task was the *Facility Operations Assessment Toolkit*. The toolkit defines, and provides documentation for, an operational assessment process with two levels of rigor:

- Option A: Existing building commissioning feasibility study
- Option B: Existing building commissioning feasibility study and cost-benefit analysis

Each of these studies employs the same site assessment approach, but Option A, uses a simplified savings estimator tool, whereas Option B, relies upon the assessor performing custom savings estimations for all identified opportunities. The report templates for each approach are different, although they share many common elements.

To maximize applicability and consistency of the facility operations assessment process, the comprehensive toolkit includes:

- Facility operations assessment process manual
- Report templates
- Facility operations assessment checklist
- Facility operations assessment field manual
- Savings estimation tool (applicable to Option A approach only)

The research, pilots, and interviews conducted were limited in number, but those surveyed expressed a strong belief that an increasing number of market stakeholders want standardized tools and methods for incorporating energy performance into the property valuation process. The research team is therefore confident that the facility operations assessment will be of interest to building owners and property condition assessment providers. As of August 31, 2012, the facility operations toolkit had been downloaded 258 times.

Tools for Existing Building Commissioning (EBCx)

The goal of this task was to develop and encourage adoption of tools and processes used by commissioning providers for existing building commissioning projects. This would, in turn, build capacity in the EBCx industry to meet growing demand, streamline complex energy savings calculations, and increase certainty in the outcomes.

The two tools developed under this task were the Energy Charting and Metrics tool v2.0, and the Custom Building Optimization Analysis existing building commissioning savings calculation tool.

Energy Charting and Metrics was originally developed by Portland Energy Conservation, Inc. (PECI), with funding from the Northwest Energy Efficiency Alliance, New Buildings Institute, and the California Energy Commission. It is a Microsoft® Excel®-based tool intended to automate many energy analysis and charting processes that are common to existing building commissioning and energy auditing. Energy Charting and Metrics (ECAM) significantly reduces energy analysis time for existing building commissioning providers and can help new existing building commissioning providers understand the range of options available for analyzing building energy use.

This task involved updating ECAM to be compatible with more recent versions of Excel, and also incorporating additional charting and analysis functionality. The resulting tool, ECAM v2.0, is a considerable improvement over the original version in terms of range of functionality and ease of use, and is supported by a comprehensive user guide. As of August 31, 2012, ECAM v2.0 had been downloaded 394 times from the following website: http://www.cacx.org/PIER/ecam/

Custom Building Optimization Analysis (C-BOA) is a new Microsoft Excel-based tool for calculating energy savings for nine common existing building commissioning measures. Historically, existing building commissioning providers have developed their own spreadsheet savings calculation tools, resulting in inconsistency of approaches. As a result, utility existing building commissioning programs have had to exert a high level of quality control in reviewing calculations, and this has been a significant challenge for improving program cost effectiveness and project timelines. In 2011, California's major utilities released the Building Optimization Analysis (BOA) tool as a standard savings calculation tool for common existing building commissioning measures. Building Optimization Analysis is targeted at measures with savings of 75,000 kilowatt hours (kWh) or less. The newly developed C-BOA tool is intended to complement BOA by addressing higher-savings measures and more complex system configurations. C-BOA covers the following measures:

- Optimize economizer performance.
- Optimize air handler scheduling.
- Optimize or reset supply air temperature.
- Reduce or reset discharge static pressure setpoint.
- Add or optimize Variable Frequency Drive (VFD) on supply fan.
- Add or optimize VFD on chilled water pump.
- Optimize or reset chilled water supply temperature.
- Optimize or reset condenser water supply temperature.
- Add or optimize VFD on cooling tower fans.

The selection of measures for inclusion in the tool and detailed tool specifications were reviewed by an independent technical advisory group comprising commissioning providers,

utility program managers, and other energy engineers. As of August 31, 2012, the Custom Building Optimization Analysis had been downloaded 716 times.

Improving the Persistence of Existing Building Commissioning Benefits (EBCx)

A common concern regarding existing building commissioning is the question of how savings from operations and maintenance improvements persist over time. The goal of this task was to identify key barriers to adopting savings persistence strategies and collect information on factors that cause the degradation of savings from EBCx measures. The research team evaluated the key managerial, organizational, financial, and technological factors that lead to best-in-class examples in managing energy performance. Findings from the research were used to develop research reports, best practice case studies, and a best practice handbook for building owners, managers, and operators. The three research reports developed were:

- *Investigating Energy Performance Tracking Strategies in the Market*. A literature review of 20 documents, 21 phone interviews with building owners and staff, and detailed on-site interviews at five buildings. This report gathered perspectives on what constitutes best practice in energy performance tracking and what factors contribute to energy performance degradation.
- *Characterization of Fault Detection and Diagnostic and Advanced Energy Information System Tools.* This research evaluated and characterized nine building performance tracking tools, with a focus on fault detection and diagnostic tools. Research was a combination of reviewing vendor-published literature on the tools and interviews with tool vendors and users.
- *Characterization of Building Performance Metrics Tracking Methodologies*. This literature review evaluated 80 documents, and included a detailed review of 23. In addition, interviews were conducted with seven individuals, including performance contractors, controls contractors, a software developer, and an energy information system business development team. This research investigated building performance metrics that can be used by building owners, energy managers, and operators to track the performance of commercial facilities.

The research team found that performance tracking tools and methods are not widely applied or well-understood. Those with tracking tools typically underused their capabilities, and the general knowledge and education of how to use various types of strategies and tools available is generally lacking. The limited information that is available is focused on technical capabilities of the tools, and not on how end users can effectively use the tools. Although some information is available on tool capabilities, there is no commonly understood and accepted framework for categorizing the landscape of energy performance tracking tools.

The research resulted in the development of the *Building Performance Tracking Handbook*. The handbook was developed primarily for property managers, energy managers, and facility engineers; it may also benefit facility service contractors and building operators. This 79-page handbook covers the fundamentals of building performance tracking, including building management aspects as well as describing the range of tools available, within the following structure:

- **Introduction to Building Performance Tracking:** What it is and how it relates to commissioning; making the business case for building performance tracking.
- **The Basics of Building Performance Tracking:** Steps to building a successful management framework for building performance tracking; energy benchmarking, utility bill analysis, building automation systems.
- **Beyond the Basics:** Energy tracking with energy information systems; tracking key system performance metrics; fault detection and diagnostic tools.
- **What's Next?:** Selecting a performance tracking approach; useful resources

The tools covered include benchmarking and utility bill analysis tools, basic and advanced energy information systems, system-level metrics using Building Automation System (BAS) data, fault detection, and diagnostic tools. The research team developed four case studies to accompany the handbook, highlighting best practice examples for both commercial and institutional buildings.

Through the outreach efforts, the handbook was presented to the Consortium for Energy Efficiency, who has adopted and shared it with member utilities across the United States. The handbook is endorsed by the California Energy Committee of the Building Owners and Managers Association (BOMA). As of August 31, 2012, the handbook had been downloaded 1,661 times, and 141 hard copies had been distributed; and the associated case studies had been downloaded 136 times

Verification of Savings from Existing Building Commissioning

The goal of this task was to resolve technical barriers to implementing effective existing building commissioning savings verification strategies, including:

- A lack of specific industry-accepted methods for measuring and verifying energy savings, and
- Absence of practical guidelines for selecting and applying different methods.

In 2008, the CCC released the *Guidelines for Verifying Existing Building Commissioning Project Savings, Using Interval Data Energy Models IPMVP Options B and C,* to promote the use of energy meter data for verifying savings from existing building commissioning projects. The method presented in the Options B and C guidelines was adapted from the International Performance Measurement and Verification Protocol (IPMVP) and sought to streamline the verification methods used in utility programs and tailor the guidance to the specific needs of existing building commissioning projects. This task was intended to review the effectiveness of the Options B and C guidelines and to incorporate this method alongside additional methods in a new guideline.

The research team conducted tests and solicited feedback from two existing building commissioning providers on the effectiveness and clarity of the Options B and C guidelines and subsequently updated the *Guidelines for Verifying Savings from Commissioning Existing Buildings*. These new guidelines define practical steps for implementing four existing building commissioning savings verification methods:

- **Method 1: Engineering Calculations with Field Verification** describes how engineering calculations used to estimate savings before implementation are subsequently used to verify actual savings. It also describes how post installation measurements are used to improve the savings estimates.
- **Method 2: System or Equipment Energy Measurement** characterizes the system or equipment energy use by its load and schedule so that each component is measured separately. The primary effect of the existing building commissioning measures on each component is used to determine post installation measurements. This method is based on retrofit isolation approaches defined by the International Performance Measurement and Verification Protocol (IPMVP) and the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Guideline 14-2002.
- **Method 3: Energy Models Using Interval Data** describes a verification method in which empirical models of baseline energy use and key independent variables are used to verify savings. It can be used to verify total savings in a whole building or for building subsystems. This measurement and verification method may be applied with IPMVP's Option C - Whole Building, or Option B - Retrofit Isolation approaches. Method 3 may also be applied in compliance with ASHRAE Guideline 14-2002, whole building performance path.
- **Method 4: Calibrated Simulation** describes the use of whole-building simulation software to develop and calibrate a building model that correctly reproduces the baseline energy use of a building and its subsystems. This simulation may then be used to model the resultant energy savings from a set of implemented measures. This method may be applied in adherence with IPMVP's Option D, or ASHRAE Guideline 14-2002.

In addition to providing step-by-step guidance for implementing each of the four methods, the research team developed criteria that can be used to determine the most suitable method for a given project. As of August 31, 2012, the *Guidelines for Verifying Savings from Commissioning Existing Buildings* had been downloaded 641 times.

Alongside the development of new guidelines, the research team developed two case studies for verification of Method 3, based on the pilot tests conducted under this task. These case studies, based on actual projects, help to clarify the situations in which Method 3 is an ideal choice and to explain the method using real data. These case studies will be posted online along with the new guidelines. The website is provided in the Program Outreach Section.

Title 24, Part 6, Acceptance Testing: Enforcement and Effectiveness

The goal of this task was to evaluate Building Energy Efficiency Standards (Title 24, Part 6) acceptance testing requirements and enforcement procedures to understand the challenges, limitations, and opportunities for achieving the intended energy efficiency. The research encompassed interviews with a variety of industry stakeholders to determine current enforcement procedures and barriers to compliance, and field work with mechanical contractors to evaluate the effectiveness of acceptance testing documentation.

The product of this research was a set of recommendations for changes to the Building Energy Efficiency Standards acceptance testing forms, enforcement procedures, and for training and

outreach. The research conducted under this task is detailed in the report *Evaluation of Title 24 Acceptance Testing Enforcement and Effectiveness*.

To assess enforcement procedures, the research team conducted 31 phone interviews with industry stakeholders, including building officials, mechanical contractors, design engineers, and building owners. In addition, researchers visited four building departments for a first-hand view of their processes. Findings from the interviews include:

- Building departments are underfunded and understaffed, thus acceptance forms receive little review, and plans examinations are often outsourced to local engineering firms.
- Building departments and the firms they employ need an improved understanding of the testing procedures and the methods for reviewing test forms. More important, they need successful models of enforcement that illustrate practical approaches for improving compliance.
- The "responsible party" is very often not specified on the forms. Thus, it is unclear who is responsible to execute tests, which can contribute to omission of the tests.

To determine the effectiveness of the acceptance test procedures, eight different contractors were enlisted to perform multiple acceptance tests at 13 commercial high-rise and low-rise buildings. The researchers observed and recorded the actual procedures used in the resulting 48 acceptance tests. A comparison of the observed procedures with the documented requirements and feedback from the contractors yielded the following conclusions:

- Most contractors are at least somewhat familiar with the tests. However, the field testing indicated that often their perceived level of understanding exceeded their actual ability to perform the specified tests.
- Technicians are unaware of reference materials such as the compliance manual.
- Confusion arises in interpretation of the procedures, as the tests are complex and the forms are unclear.
- Contractor training is insufficient. Roughly half of the tests could not be performed without a moderate or substantial level of coaching.

Based on the findings from the field testing, the research team drafted updates to acceptance testing forms that were intended to help address some of the identified challenges. The updated forms were forwarded to Energy Commission staff for review. Energy Commission staff approved the updated forms, and they have been incorporated in the updated standards; at the time of writing this report, the updated standards are undergoing public review.

Beyond documenting the research in a formal report, the research team also created three documents specifically designed to help address some of the challenges raised in the research:

- **Acceptance Testing Infographic:** This infographic describes each of the steps in the process and highlights the people involved, the key documents, and decision points.
- **Acceptance Testing Bid Sheet:** The document is designed to accompany a bid for services that includes acceptance testing; it describes acceptance testing requirements, explains that acceptance testing is mandatory, and describes the long-term benefits of healthy and efficient buildings.

- **Contractor Case Study:** This case study outlines a contractor's approach to acceptance testing, the challenges faced, and the benefits realized in terms of building performance and business success for the contractor.

Printed copies of these documents have been distributed to organizations in California with market connections to stakeholders involved in Title 24 acceptance testing.

Program Outreach

Each task under this program incorporated an outreach component. Multiple outreach methods were employed, tailored to each task's deliverables and target audience. In general, documents developed under this program were designed for Web-posting to limit materials use and transportation impacts; the exceptions were printed versions of the *Building Performance Tracking Handbook* and Title 24 outreach materials.

The CCC developed new Web pages to describe each of the research tasks and to post research reports, and created separate pages for posting the tools and guidelines. The rationale for separate pages was that the target audience for the tools and guidelines was expected to be primarily interested in the tools themselves, and less so the associated research. The new tools and guidelines significantly bolster the CCC's overall resources toolkit, and have received regular publicity through CCC mailings, webinars, and in-person meetings. The CCC website where the products from this research can be downloaded is:
http://www.cacx.org/resources/rcxtools/

Targeted outreach strategies employed through this program included:

- **Presentations:** Researchers presented program outcomes and deliverables at conferences, industry meetings, and webinars.
- **Articles:** Press releases and articles featured in print media, electronic newsletters, and on industry websites.
- **Web-Based Video Tutorials:** A series of short Web-based tutorials were developed for Energy Charting and Metrics and C-BOA, covering a range of each tool's functionality.
- **Social Media:** CCC staff used LinkedIn® and Twitter® Web-based social networking to publicize the provided project goods and services under this program and to engage industry peers in dialog on research-related topics.
- **Training Program Outreach:** The Facility Operations Assessment toolkit is featured in the course "Case Studies in Appraising Green Commercial Buildings" presented by the Appraisal Institute.
- **Utility-Focused Outreach:** Researchers held meetings with utility program representatives to promote new tools and guidelines.

CCC tracks downloads of Web-based documents and will continue to seek opportunities to promote the tools and guidelines developed under this program. CCC's connections with utility program implementers and existing building commissioning providers present regular opportunities to support market adoption, as do the regular meetings and webinars hosted by the CCC.

Conclusions and Next Steps

The integrated research and development program *Building Commissioning: Strategies and Technologies for Energy Efficiency* met all of its goals. The tools and guidelines developed under this program directly contribute to the California Public Utilities Commission's Energy Efficiency Strategic Plan, under Goal 2-5-2: **"**Strengthen Tools and Practices for Building Commissioning" for commercial buildings. CCC's work under this program has been recognized in the strategic plan status update documents as providing leadership and progress in the building commissioning field.

Without this program, the research team believes it highly unlikely that these freely available tools and guidelines would have been developed. Their release is timely, as 2013 will mark the start of a two-year utility program "transition period," and the CCC will be collaborating with the utilities to support adoption of these new resources.

The research program management team coordinated the efforts of seven firms, with support from technical advisory groups and the program advisory committee comprising more than 90 industry experts. In addition, the research teams engaged with numerous other industry experts and contractors and placed program goods and services in front of tens of thousands of industry stakeholders.

In addition to Public Interest Energy Research Program funding, this R&D benefited from an additional $120,000 of match funding from the CCC, the Northwest Energy Efficiency Alliance, and Southern California Edison.

While the CCC is confident that the new resources developed under this program can help address barriers to greater market penetration of existing building commissioning, it is too soon to assess their effects (beyond counting downloads of documents and collecting user feedback). The CCC is committed, and uniquely placed, to continue support for market adoption through its connections to existing building commissioning program administrators and existing building commissioning providers.

The research team's recommended next steps include energy efficiency program integration and promoting standardization of existing building commissioning outside of programs:

Energy Efficiency Program Integration

Utility existing building commissioning programs have typically been high cost with high labor input compared to retrofit programs. This is due to the complexity of the existing building commissioning process and the lack of standardization among existing building commissioning providers' work. This research and development program has resulted in a wide range of tools and guidelines designed to address the cost and labor barriers. The research teams conducted a range of successful outreach activities, and further activities are recommended to ensure the benefits of these tools and guidelines are fully realized:

- **Encourage adoption of new tools and guidelines by providers and program managers:** Additional training resources, phone or e-mail support for users, and documentation

may be necessary to ensure that programs can fully use the new resources developed under this program.

- **Develop programmatic approaches with integrated building performance tracking tools:** While these tools show great promise for improving building energy management, integration into programs will require research into their technical capabilities for measuring savings impacts, driving behavioral changes, identifying measures, and improving persistence of savings.
- **Support whole building approaches capturing retrofit, operational, and behavioral savings:** Standardized savings verification approaches and the use of building performance tracking tools open up opportunities for integrated demand-side management approaches. Industry collaboration and research is needed to determine how best to apply integrated demand-side approaches within regulatory and program management frameworks which are tailored to non-integrated approaches.
- **Incorporate tools and guidelines into the Energy Commission's Comprehensive Energy Efficiency Program for Existing Buildings (Assembly Bill 758 [Skinner, Chapter 470, Statutes of 2009):** The AB 758 program is in the early development phase, and "energy assessments" are a key component in the program. Existing building commissioning can be one assessment approach offered through the program, and the CCC should work to ensure that its resources are in the AB 758 program guidelines.

The start of the California utilities' "transition" program cycle in 2013 provides a timely opportunity to increase quality and consistency of existing building commissioning projects in California through adoption of the CCC's tools and guidelines, in time for the start of the next full program cycle in 2015.

Standardization of EBCx Outside of Programs

Improving cost-effectiveness of existing utility EBCx programs was one of the primary goals of this program, but the ultimate goal is market transformation: creating market conditions whereby existing building commissioning is business as usual, in the absence of utility incentives. To move toward market transformation, the research team has the following recommendations:

- **Clarify the EBCx business case for building owners and managers and develop financial decision-making tools to support existing building commissioning investments:** Existing building commissioning, along with energy efficiency in general, is often promoted for its energy savings potential with a low, simple payback. Building owners and managers seldom make investment decisions based on those two metrics, and so it is recommended to develop tools that will support the metrics and processes that are most commonly used (net present value instead of simple payback, for example). The value proposition for owners will also be improved if non-energy benefits such as occupant comfort can be promoted more strongly.
- **Engage market stakeholders in the property valuation community to promote operational assessments at time of sale:** If the value of existing building commissioning to building owners and managers can be strengthened, then it follows that they may be

interested in assessing existing building commissioning potential for a prospective purchase. The property valuation community needs to establish standardized methods for incorporating operational assessment into the transaction process, and the Facility Operations Assessment toolkit provides a starting point.

- **Develop existing building commissioning approaches for hard-to-reach building/owner types:** Properties smaller than 100,000 square feet and multitenant properties where tenants pay all energy costs are examples of property types for which existing building commissioning market penetration is very low. Increasing existing building commissioning within these hard-to-reach market sectors may require new tools, marketing approaches, and project delivery infrastructure.
- **Collaborate with influential industry organizations within California, and tailor existing building commissioning processes to owner needs outside utility regulatory structures:** The existing building commissioning process is typically structured around the needs of utility programs and program evaluation protocols. Successful market transformation will require collaboration between many industry stakeholders to develop the ideal EBCx approach in terms of low cost, low risk, and maximizing energy and non-energy benefits.

Achieving standardization outside of utility programs would require collaboration between industry organizations to determine the most effective ways of moving toward market transformation. This includes organizations such as the Building Owners and Managers Association (BOMA), the International Facility Managers Association (IFMA), and the California Chapter of the Building Commissioning Association (BCA). The evolution of utility existing building commissioning programs to date has largely been driven by regulatory, cost-effectiveness, and program management-related factors. Moving to a market-driven approach will involve different considerations and financial metrics, and so it will be important to involve the relevant stakeholders in taking leadership.

Benefits to California

The integrated research and development program *Building Commissioning: Strategies and Technologies for Energy Efficiency* developed a suite of new tools and guidelines designed to address technical and market barriers aimed at increasing adoption of existing building commissioning in California. Market adoption of these new tools and guidelines is expected to play a key role in the evolution of existing building commissioning from a niche engineering specialty to being business as usual. These new tools are expected to benefit California's utility program efforts, and support California building owners and contractors who implement projects outside of utility programs. With these tools, building owners can increase the energy efficiency of its lighting, HVAC and other systems with minimal capital cost. The benefits include energy and cost savings to building owners and its associated reduction in greenhouse gas emissions. Existing building energy use can be reduced by an estimated 16 percent annually due to building commissioning. Additional benefits include improved working and learning environments for building occupants.

CHAPTER 1: Introduction

1.1 Background

Existing Building Commissioning (EBCx)[1] improves the energy performance of buildings by ensuring that systems and equipment operate as designed and that building facility staff are able to operate and maintain them effectively. Research on past EBCx projects has shown median project savings of 16 percent, with a simple payback of 1.1 years[2], a relatively high rate of return when compared with equipment replacement projects. However, the technical complexity and lack of market understanding of the EBCx process, benefits, and outcomes create challenges that hinder widespread implementation of the practice and reduce the realization of energy savings.

The California Energy Efficiency Strategic Plan (Strategic Plan), developed by the California Public Utilities Commission (CPUC) identified a need to "Develop tools and strategies to use information and behavioral strategies, commissioning, and training to reduce energy consumption in commercial buildings."[3] Since its creation in 2000 the California Commissioning Collaborative (CCC) has been a resource providing tools and strategies to support commissioning, and the Strategic Plan recognized that there were gaps in both the range of tools and the extent of their application.

The program *Building Commissioning: Strategies and Technologies for Energy Efficiency,* funded by the California Energy Commission's Public Interest Energy Research (PIER) Program, intended to support the Strategic Plan. Furthermore, the program was to implement some of the recommendations from a previous PIER-funded program *Commercial Commissioning Research and Development* (Contract CEC-500-05-035), which resulted in market research, development of the CCC's EBCx toolkit, and development of a guideline for verifying savings from EBCx projects.

The CCC) is a California nonprofit public benefit corporation, created in 2000. Its purpose is:

- To improve building and system performance by developing and promoting viable building commissioning practices in California.

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1 The term EBCx is used in this report as a generic term encompassing retrocommissioning, Retro Commissioning (RCx), and recommissioning.

2 Mills, Evan (Lawrence Berkeley National Laboratory). 2009. *Building Commissioning: A Golden Opportunity for Reducing Energy Costs and Greenhouse Gas Emissions*. Lawrence Berkeley National Laboratory. http://cx.lbl.gov/documents/2009-assessment/lbnl-cx-cost-benefit.pdf

3 California Energy Efficiency Strategic Plan, Section 3, Commercial Sector, Strategy 2.5. www.cpuc.ca.gov/NR/rdonlyres/A54B59C2-D571-440D-9477-3363726F573A/0/CAEnergyEfficiencyStrategicPlan_Jan2011.pdf

- To facilitate the development of cost effective programs, tools, techniques and service delivery infrastructure to enable the implementation of building commissioning processes.
- To educate and inform building commissioning processes.
- To identify opportunities, establish priorities and promote solutions relating to building commissioning processes in California.

The CCC hosts regular public meetings and webinars, and provides a wide range of resources through its website – all free of charge.

1.2 Research Program Goals

The purpose of this integrated research and development (R&D) program was to address market and technical barriers that hinder widespread implementation of the commissioning practice to deliver energy savings to California buildings. The overall goals of this program were to:

- Simplify decision-making by providing building owners with actionable energy information that will put them on the path to implementing commissioning in their properties.
- Strengthen commissioning practices by developing standardized tools and processes for providers, owners, and other industry stakeholders to enable more effective implementation of EBCx and long-term persistence of benefits.
- Quantify the savings from EBCx by developing guidance for the selection and implementation of verification methods that are appropriate for EBCx projects.
- Increase building energy efficiency by supporting the Energy Commission in improving the technical feasibility and compliance with acceptance testing requirements in California's building energy efficiency code (Title 24, Part 6).

To address this broad set of goals, the research program comprised the following five separate but related technical tasks, in addition to a program administration task:

- Task 1: Program Administration
- Task 2: Optimizing Integration of Energy Information and EBCx Services in Commercial Real Estate Transactions
- Task 3: Tools for Standardizing the EBCx Process
- Task 4: Improving the Persistence of EBCx Benefits
- Task 5: Verification of Energy Savings from EBCx
- Task 6: Title 24 Acceptance Testing Requirements and Effectiveness

Each of the technical tasks is described in full in Chapters 2 through 6.

1.3 Research Program Approach

The CCC engaged a team of seven firms with a range of specialties to perform work under this program. Major subcontractors were Portland Energy Conservation, Inc., (PECI), Quantum Energy Services and Technologies (QuEST), Architectural Energy Corporation (AEC), and

Enovity. Minor subcontractors were Eaton, Heschong Mahone Group, and EnerNOC. Specific program and project roles were defined as follows:

Each of the tasks completed under this program was defined separately and had its own defined team of CCC staff (there were several instances of individuals being involved in multiple tasks). Wherever possible, connections between tasks were emphasized – for example, the savings calculation tool developed under Task 3 is referenced in the guidelines for verifying EBCx project savings developed under Task 5.

External support for the program was provided in two forms:

- **Technical Advisory Groups (TAGs):** The scope for four of the tasks called for a voluntary advisory group who would convene multiple times through the course of task development. These groups provided comments and suggested edits on specification documents, draft and final deliverables, etc. Participation in TAGs was 'open-invitation,' and included utility representatives, national laboratories, researchers, commissioning providers, and service contractors.
- **Program Advisory Committee (PAC):** The CCC's Advisory Council, a volunteer sub-group within the CCC, performed the role of PAC for this program. PAC meetings were held as part of the CCC's regular in-person meetings, and involved a presentation of program status by the Research Program Manager and the Energy Commission Project Manager. The PAC meetings were intended for discussion of program-wide issues such as how to best achieve integration between tasks and how to manage program outreach.

Among the five technical tasks under this program, there were varying degrees of research (primary and secondary) and development. Throughout the program the CCC maintained a firm commitment that the tools and guidelines developed should provide maximum value to the target audience: commissioning providers, program implementers, building owners and managers. Two examples of this commitment:

- When developing Custom Building Optimization Analysis (C-BOA), an EBCx savings calculation tool, the task scope called for the tool to cover six EBCx measures. The research team identified three further measures that would be useful additions to the tool, and was able to secure additional match funding that would allow for development of these additional measures.
- Tasked with developing a handbook that would improve persistence of EBCx savings through performance monitoring, the research team determined that a handbook covering all aspects of monitoring would benefit not only those owners undertaking EBCx but all owners wishing to better manage energy performance. Subtly shifting the emphasis of the handbook had no impact on budget, but greatly increased the breadth of appeal to commercial building owners.

Each of the published reports, tools, and guidelines was developed collaboratively, subjected to extensive peer review, and was subject to a secondary level of review through TAGs and the PAC. As a result, the deliverables were technically comprehensive and were rigorously evaluated by readers with a variety of backgrounds. Where possible, the CCC has applied

similar document design formatting so that deliverables can be recognized as part of an overall "EBCx toolkit," and this extended to the design of the CCC web pages from which these deliverables are downloaded.

CHAPTER 2:
Optimizing Integration of Energy Information and EBCx Services in Commercial Real Estate Transactions

This task's scope was developed after a previous CCC project[4] identified the property condition assessment (PCA) as an opportunity to improve the transparency of energy performance at the time of sale.

The overall goal of this task was to pilot and deploy a technical and market approach to improve the transparency of energy performance, and to increase the capacity of PCA firms to provide energy assessment services. More specifically, it was intended that the developed approach would meet these criteria:

- Includes both an assessment of risk (current energy performance of the facility) and opportunity (potential for improvement through EBCx).
- Easily integrates into the normal due diligence process, without causing significant additional time, effort, or cost to parties involved.
- Is simple enough to be adopted by current PCA providers[5] without significant additional training.
- Results in reports with information on the building that is valuable and attractive to the building owner.
- Can be provided at a reasonable price point for commercial property owners.
- Is repeatable and enables industry-wide consistency in applying the approach.

By integrating an energy performance assessment into the PCA process, the benefit is not only transparency but also gaining an indication of potential to make energy performance improvements, and ideally motivating the new owner to pursue EBCx or retrofits after purchasing the property.

Detailed description of the research and development under this task can be found in the report *The Facility Operations Assessment: Development of An Operational Assessment Protocol to Support Commercial Property Transactions*[6].

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4 Market research conducted by California Commissioning Collaborative for the Energy Commission, under contract 500-05-035. Research focused on commercial real estate stakeholder decision-making and priorities, and opportunities for utilizing the transaction process as an opportunity to raise energy awareness.

5 The term "PCA Provider" is used as a generic term in this report to indicate an individual or firm who provides property condition assessment services. This term is used in the absence of any industry-accepted term; in practice, PCAs are provided by a wide variety of firms.

6 Crowe, Eliot, Emilia Sibley (PECI). 2011. *The Facility Operations Assessment: Development of an operational assessment protocol to support commercial property transactions.* California Commissioning

2.1 Research & Development Approach

The research methods employed for this task included secondary research, in-person and phone interviews with industry experts, and in-building pilots that tested several assessment approaches. The in-building pilots initially set out to test three approaches of varying rigor and cost, as indicated in Table 1.

Table 1: The Three Approaches Considered for Inclusion in Commercial Property Transactions

Approach	Description	Rigor	Cost / Effort
ENERGY STAR benchmarking	Comparison of current energy performance of a facility to that of similar facilities through ENERGY STAR® Portfolio Manager	**Very Low:** ENERGY STAR score is not considered a reliable indicator of magnitude of potential operational savings	**Low:** Tool is free. Some labor required to collect and enter data
EBCx screening	In-building walk-through to identify indicators that a building is a good candidate for EBCx.	**Low:** Limited time and data collection cannot provide estimation of magnitude of potential operational savings. Varies depending on process and practitioner.	**Medium:** 3-5 hours on-site, 3-5 hours preparation and reporting time
EBCx scoping	In-depth walk-through to determine applicability for EBCx, and also define an initial list of potential improvement measures. Provides cost and savings estimates for measures.	**Medium:** Data collection, operator interview, and cost/savings estimates provide higher confidence in results. Varies depending on practitioner.	**High:** 8-16 hours on site, 12-24 hours preparation, calculations, reporting

The central hypotheses tested through this task was to determine the following: whether providing energy performance information would result in operational improvements:

- Is providing energy performance information a service for which potential buyers would be willing to pay, as part of due diligence for commercial properties.

Collaborative. Available at http://www.cacx.org/resources/rcxtools/foa/CRE_Final_Report_on_Pilot_Project.pdf

- Could this easily be integrated into typical due diligence process and timeline.
- Is an offering that PCA providers would be interested in adding to their services.
- Could be provided by the existing pool of PCA providers.
- Could be defined in such a way as to be technically robust and repeatable in the face of varying properties and PCA provider skill level and experience.

The task was divided into two stages: Background research to confirm whether the goals and plan developed by the CCC in 2008 required adjustment, and pilots at six commercial properties to evaluate and refine approaches to assessing energy performance.

By the time this task commenced, California Assembly Bill 1103 (Saldana, Chapter 533, Statutes of 2007), the Commercial Building Energy Use Disclosure Program, had been passed, mandating that a building's ENERGY STAR score should be disclosed to a potential buyer for commercial properties[7]. As a result, the focus of this task shifted to evaluating two approaches – EBCx screening and scoping – with ENERGY STAR benchmarking being an integral element of both approaches.

The research team approached the research and development in a qualitative and dynamic fashion. The budget did not allow for a high volume of industry interviews or pilots, and so the goal was to gather deep qualitative data from a small sample group that would inform the development process. Given the small number of planned pilots, the research team avoided a rigid approach of applying identical approaches for every pilot, instead adopting a dynamic approach of ongoing refinement of the approaches based on lessons learned from each pilot.

2.2 The Facility Operations Assessment Toolkit

The research team's interviews and pilots, supplemented by ongoing informal literature review, provided valuable inputs for developing the final assessment process; qualitative information was gathered on the skills of PCA providers, owner concerns, the due diligence process as a whole, and desirable elements for the assessment reports. The research did not, however, point towards a clear preference for the EBCx screening or scoping approach. Among the relatively small group of interviewees and pilot participants there were varying opinions: some considered that the value of an assessment is very limited if it cannot provide the cost/benefit data that comes with a scoping; others felt that a scoping may be too expensive for a commercial transaction process, and that the high level information provided by a screening would be preferred.

Based on the lack of a clear preference between screening and scoping, the research team decided to develop an assessment process that included screening and scoping as variants. Naming of the assessment process was one of the many issues on which the PAC was

7 Assembly Bill 1103 will require disclosure of ENERGY STAR® rating for nonresidential buildings at time of sale, refinance, or lease. Requirement is due to take effect July 1st, 2013. More details at http://www.energy.ca.gov/ab1103/

consulted, and the research team's industry contacts were also consulted; final process naming and descriptions are summarized in Table 2.

Table 2: Summary of Final Recommended Property Assessment Approach

Facility Operations Assessment,

Option A: Existing Building Commissioning Feasibility Study

- Energy usage data and benchmarking scores. Includes current values alongside potential future values if EBCx is performed
- List of potential EBCx opportunities (selected from a list of the top 12 common EBCx measures)
- High level assessment of commissionability, based on the presence of key factors influencing the ease and cost-effectiveness of commissioning
- Yes / no recommendation for pursuing EBCx
- 4-8 hours on site, 8-16 hours preparation and reporting

Facility Operations Assessment,

Option B: Existing Building Commissioning Feasibility Study and Cost Benefit Analysis

- All of the items included in Option A
- In addition, costs and savings estimated for potential measures
- 8-16 hours on site, 16-24 hours preparation and reporting

Selection of the top 12 common EBCx measures was determined based on analysis of a dataset of EBCx measures reported for nationwide utility programs. The research team had access to the dataset used to create the report *A Study on Energy Savings and Measure Cost Effectiveness of Existing Building Commissioning*[8].

8 Effinger, Joan, Hannah Friedman, Christopher Morales, Emilia Sibley, Sarah Tingey (PECI). 2009. *A Study on Energy Savings and Measure Cost Effectiveness of Existing Building Commissioning.* PECI. Available at http://www.peci.org/sites/default/files/annex_report.pdf

Once the Facility Operations Assessment (FOA) process was defined, the research team developed a comprehensive toolkit, comprising:

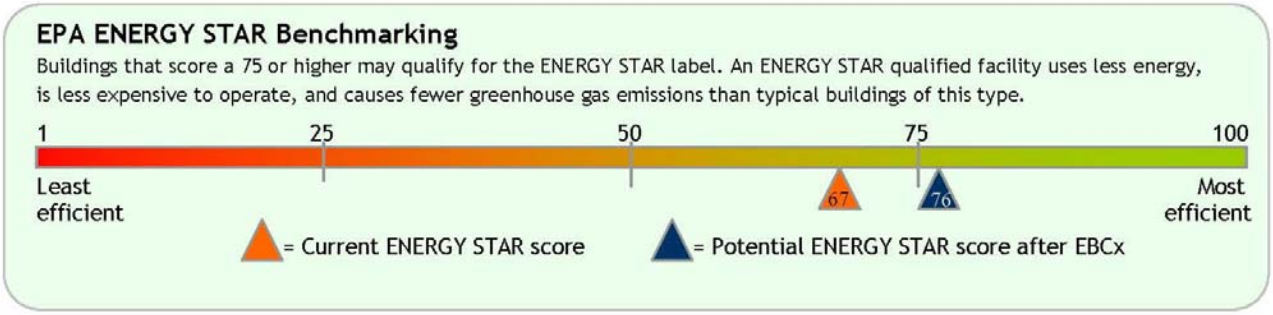
2.2.1 Facility Operations Assessment (FOA) Process Manual

This manual encompasses the entire assessment process, describing each of the stages of an FOA, the required documents, and the stakeholders involved in the process.

2.2.2 Option A and Option B Report Templates

The FOA process results in a report to the building representative with recommendations for improvement, and a report template was created for each approach (Options A and B). Figure 1 indicates a portion of the report that indicates the potential for an improved ENERGY STAR benchmark based on proposed improvement measures. Detailed addenda templates were also developed, to document the data sources and assumptions behind the summary report.

Figure 1: Excerpt from FOA Option B Report



Source: California Commissioning Collaborative. © 2012

2.2.3 FOA Checklist

The checklist is the key tool that enables PCA providers to conduct the building walkthrough, determine where indicators of energy-saving improvements exist, and identify factors that contribute to the 'commissionability' of a property. Commissionability refers to those factors that do not directly contribute to energy savings potential but can affect the feasibility and/or cost of performing EBCx; for example, comprehensive building documentation can make an EBCx project less labor-intensive although it does not increase savings potential.

2.2.4 FOA Field Manual

The field manual outlines the overall process, and provides deeper guidance on how to interpret the data collected via the checklist. The manual also notes any caveats or cautions, so that PCA providers do not rely solely on a checkbox in drawing conclusions regarding opportunities.

2.2.5 Option A Savings Estimation Tool

The FOA Option A approach requires an EBCx recommendation to be made in the absence of site-specific savings & cost estimates (Option B requires the provider to develop custom cost/savings estimations). The Option A Savings Estimation Tool is a spreadsheet tool that derives a recommendation based on checking boxes to indicate the presence of particular opportunities.

For each of the 12 most common EBCx opportunities the tool incorporates estimated cost and savings per square foot, based on industry data from 959 EBCx measures[9] implemented through utility EBCx programs nationwide. The tool calculates estimated project costs (including estimated cost for EBCx investigation, and measurement & verification) and savings, and then converts these values into "low/medium/high" approximations. The approximation is based on two inputs: overall savings percentage and return on investment (ROI). This approximation of low/medium/high feasibility is applied because actual dollar values for costs and savings could erroneously imply that a more rigorous and site-specific approach has been taken for deriving recommendations.

Once the FOA documentation was completed, it was sent to one of the PCA providers who participated in pilots, for their review. The reviewer assessed the suitability of the documentation for a 'typical' PCA provider, clarity of the documentation, and whether the reporting provided the type and level of detail desired by a potential property buyer. The reviewer had only minor formatting comments, and feedback was very positive. Once all documentation was finalized, the CCC developed a custom web page where the toolkit available for free download[10].

2.3 Facility Operations Assessment: Outreach

Outreach promoting the FOA targeted three stakeholder groups: Building owners, PCA providers, and policymakers. Outreach activities are summarized below.

2.3.1 Owner & PCA Provider Outreach

Outreach to owners and PCA providers overlapped to some degree, as they share some common resources in terms of journals, social media, and conferences. The outcomes of the project team's outreach included:

- Sponsorship of the Urban Land Institute (ULI) fall meeting, October 2012. Sponsorship was at the level "Friend of the Meeting," which included an Exposition Booth for the three days of the meeting. The Urban Land Institute represents property owners, investors, developers, and related service providers and consultants.
- Co-presenting a webinar for CoStar's "Current Trends in Real Estate" quarterly webinar series, along with Anthony Guma of CoStar and Theddi Wright Chappell of Cushman

9 Ibid at 9

10 See http://www.cacx.org/resources/rcxtools/foa/

Wakefield. The webinar title was "Property Valuation," and the sub-title relating to the FOA was "Benchmarking and beyond - tools to assess building performance."

- An article in National Real Estate Investor Online: *Energy Efficiency: The Pot of Gold Hidden Under the Floorboards.*[11]
- An article in the Scotsman Guide, a print/online publication: *Shedding Light on Green Value.*[12]
- Inclusion of the FOA in a course offered by the Appraisal Institute (AI), titled "Case Studies in Valuing Green Commercial Properties[13]." This course is being offered as part of the AI's "Valuation of Sustainable Buildings Professional Development Program." An overview of the FOA is included in this course as an example of a tool for PCA providers to offer their clients.
- Announcements posted to multiple groups on the LinkedIn social networking site.

The full impacts of outreach are very difficult to quantify, as the CCC's FOA web page only went live in August 2012, and the outreach activities listed above were conducted in September and October 2012. As of August 31, 2012, the FOA Toolkit had been downloaded 258 times. While the program contract ends in October 2012, the CCC will continue to monitor downloads of the toolkit and will look for opportunities for further publicity.

2.3.2 Policymaker Outreach

The policymaker outreach sub-task was targeted at directing the benefits from this project into California's policy-related activities. The research team identified two relevant policy efforts, AB 1103 and Assembly Bill 758 (Skinner, Chapter 470, Statutes of 2009), which are summarized below.

AB 1103 - Commercial Building Energy Use Disclosure Program: This bill mandates disclosure of a commercial property's ENERGY STAR score at time of sale, refinancing, or if the building is leased in its entirety. Disclosure is restricted to the parties involved in the transaction. While the bill was passed in 2007, it will not go into effect until mid-2013 at the earliest. Energy Commission staff responsible for implementing AB 1103 were made aware of the FOA process, although the timing and passage of AB 1103 implementation makes it unfeasible to even consider adding the FOA to this legislation at this time.

Assembly Bill 758 – Comprehensive Energy Efficiency Program for Existing Buildings[14]: This bill directs the Energy Commission to develop and implement a Comprehensive Energy Efficiency Program for Existing Buildings, and the bill specifically mentions time-of-sale

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11 See http://blog.nreionline.com/nrei-writes/2012/09/14/energy-efficiency-the-pot-of-gold-hidden-under-the-floorboards/

12 See http://scotsmanguide.com/default.asp?ID=5382

13 More details at http://www.appraisalinstitute.org/education/course_descrb/Default.aspx?prgrm_nbr=828&key_type=C

14 See http://www.energy.ca.gov/ab758/ for more details.

program elements as a consideration. The bill was passed in 2009 and is currently in the program scoping and planning stage.

The Principal Investigator for this task, along with the lead engineer on the task, is also engaged in providing technical support to the Energy Commission on the AB 758 Program. As a result, all of the lessons learned from this task can automatically and smoothly be transferred to the AB 758 project. The outreach efforts for this task were therefore redirected, at the direction of the Energy Commission Project Manager; outreach efforts included presenting the FOA process and toolkit to:

- The Energy Commission's lead engineers for the nonresidential portion of AB 758
- The project team working on the U.S.DOE's Commercial Asset Rating development (U.S. DOE and Pacific Northwest National Laboratory).
- The Institute for Market Transformation (while IMT are not policymakers as such, they are the foremost authority for summarizing, and to some degree influencing, policy development in the U.S.).

These outreach efforts intentionally spread beyond California's borders – aligning time-of-sale policies nationwide is a valuable strategy for easing policy implementation, such as sharing policy best practices, and improving ease of compliance for property owners with national portfolios of buildings.

2.4 Facility Operations Assessment: Conclusions and Next Steps

Research, development, and outreach conducted under this task were considered successful – the research confirmed some assumptions and provided direction on aspects that were uncertain or unknown. The FOA toolkit is a comprehensive new industry resource and has been incorporated into the CCC's overall toolkit for existing buildings. Outreach successfully targeted some high profile outlets aimed at the target audience.

While it is acknowledged that the research, pilots, and interviews conducted under this project were limited in number, those surveyed expressed a strong belief that some market stakeholders are seeking tools and methods for incorporating energy performance assessment into the property valuation process. The research team is confident that the FOA will be of interest to building owners and PCA providers (it may also draw commissioning providers in to support the property valuation process). In order for the FOA to become established at scale, the research team has the following recommendations:

- **Conduct a larger set of pilots.** The pilots conducted under this project were highly valuable in defining the process. It is expected that a greater number of pilots could lead to further refinements, and also help in developing training materials for practitioners who wish to incorporate the FOA into their service offerings.
- **Development of a formal FOA standard.** Once the FOA process has been honed through further pilots, developing a formal national standard (e.g. an ASTM standard) would be an ideal next step. This would have two benefits: first, of course, it would result in the standard itself; second, it would necessitate the involvement of a very broad

set of stakeholders including building owners, brokers, underwriters, PCA providers, etc., who would thereby become intimately knowledgeable about the standard.

- **Development of software tools.** The FOA toolkit is considered a valuable and usable resource; however, to reach scale in the marketplace it may be beneficial if the process could be integrated into software applications. There would be two likely options for addressing this need: to develop standalone software, or to develop an Application Programming Interface (API) that could be incorporated into any software program developed by a third party (in the same way that Google® Maps can be embedded into any web page design). It is recommended to perform market research before developing software, to confirm the need and evaluate current tools being used by PCA providers.

The FOA process provides a new tool that can be applied during commercial property due diligence, and there is also a secondary application: an FOA may be used by a property owner or manager to assess their existing buildings, irrespective of whether they are due to be sold. The CCC will continue to seek opportunities to promote the process for either application.

CHAPTER 3:
Tools for Existing Building Commissioning

The goal of this task was to develop and encourage adoption of tools and processes used by commissioning providers for EBCx projects. This would in turn build capacity in the EBCx industry to meet growing demand, streamline complex energy savings calculations, and increase certainty in the outcomes of EBCx. For California's utility programs, the diversity and varying quality of EBCx savings calculations has typically required high levels of scrutiny and multiple review iterations, which are both time- and cost-intensive. The tools developed under this task were intended to help address these challenges.

3.1 Research & Development Approach

In contrast to the previous task, developing the FOA process, this task was predominantly development with relatively little primary or secondary research being required.

Updating the ECAM spreadsheet tool involved the addition of new analysis and charting functionality, along with updating the tool to be compatible with more recent Microsoft® Excel® software. Once updated, the tool was evaluated by four engineers who had not been directly involved in tool development, two of whom had prior experience with the existing version of ECAM. The tool was then finalized, and user documentation was completed. The user guidance was supplemented by a series of short web-based video tutorials, guiding users through a range of ECAM functionality.

Development of the C-BOA savings calculation tool involved pooling the knowledge of the CCC and its two subcontractors in developing high quality energy savings calculations. Engineers from each firm had past field experience as EBCx providers, and also had performed numerous reviews of EBCx provider savings calculations on behalf of California utility programs. With this experience, the team had a deep understanding of the quality control requirements of the utilities, along with real-world experience of what input data is typically available to EBCx providers.

The C-BOA tool development started with creation of a detailed tool specification. Once developed, modifying a savings calculation tool can be highly complex, and so the tool specification was crucial for enabling the team, the Energy Commission, and the TAG to understand the design intent and expected functionality of the tool prior to starting tool development.

C-BOA was developed as a Microsoft Excel spreadsheet calculation tool, with embedded macros and datasets (e.g. typical weather data for all of California's climate zones). Microsoft Excel was chosen as it provided greater flexibility and transparency compared with other methods such as using simulated parametric runs. It is also a tool with which all EBCx providers would be expected to have familiarity.

The tool development process was iterative, with AEC leading the development and Eaton Corporation and CCC Staff as tool testers.

The TAG for this task was engaged multiple times to provide comment and input on both ECAM and C-BOA development.

3.2 Energy Charting and Metrics (ECAM) Tool, v2.0

ECAM was originally developed by PECI, with funding from the Northwest Energy Efficiency Alliance (NEEA), New Buildings Institute (NBI), and the Energy Commission's PIER Program. It is intended to automate many energy analysis and charting processes that are common to EBCx and energy auditing – ECAM has two primary benefits: firstly, it can significantly reduce energy analysis time for EBCx providers, and secondly it can assist new EBCx providers in understanding the range of options available for analyzing building energy use.

The tool has been available for free download from the CCC's website since 2008, but the original version of ECAM was only compatible with Microsoft Excel versions up to 2003, which is gradually becoming obsolete. Additional justification for developing "ECAM v2.0" was that user feedback had provided suggestions for additional functionality, and Microsoft Excel 2007/2010 includes many charting-related improvements.

ECAM was updated by the engineer who originally developed the tool, and this same engineer also conducted most of the validation testing. Additional user testing and feedback was provided by four engineers, two of whom were already familiar with ECAM. Under this task, the following general updates were incorporated into ECAM v2.0:

- Add Excel 2007 and 2010 capability.
- Extend list of typical Holidays.
- Add additional error checking for inputs and handle improper user execution order.
- Add error checking for whether the menu icons are available during menu creation.
- Check instances where the calculation mode is set to manual, to make sure that it is always set back to the user's calculation setting.
- Provide a means to add in new data or points, or instruct users to add new data within original data range.
- Correct automatic creation of additional fields for metrics.
- Startup and shutdown time periods can now be entered, in addition to occupied/unoccupied periods.

The following additional charting capabilities were also added:

- Time-series history (of all timestamps).
- Weekly load profiles.
- Scatter chart with all data, instead of averaged data.
- Load-Duration Chart.
- Load profiles as grouped box plots.
- Chart to check schedule.

The following improvements were made to existing charting capabilities:

- Automatic Scales Adjustment.
- Ability to copy worksheet with chart, and keep PivotTable chart references.
- Chart Matrices.

The following metrics features were added or modified:

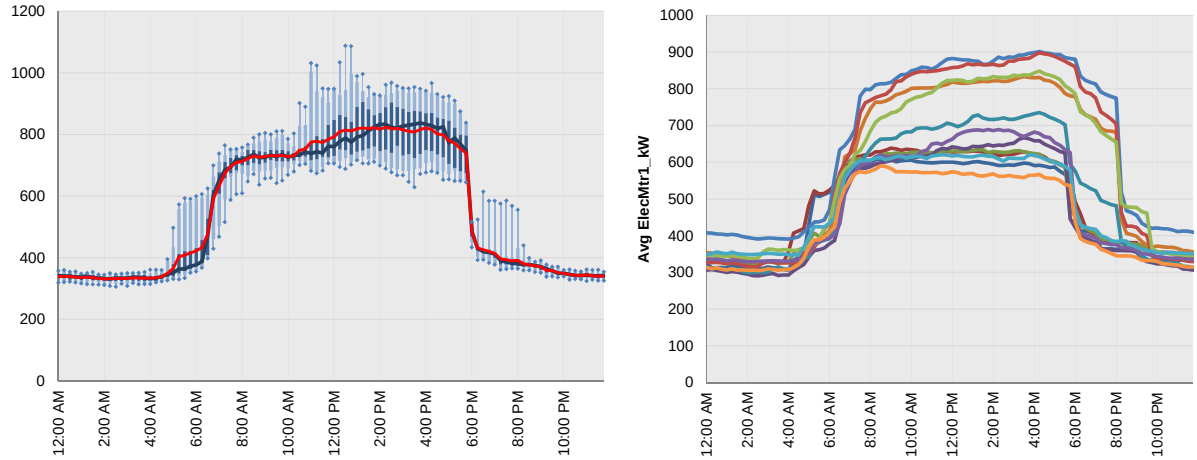
- Occupancy and Month-Year combination; Day type and Month-Year combination.
- Ratio of typical low (unoccupied) demand to typical high (occupied) demand.

Data summary functionality was enhanced, to include the following statistics:

- Maximum.
- 90th Percentile.
- Median.
- 10th Percentile.
- Minimum.
- Average.
- Standard Deviation.

Figure 2 shows examples of two charts generated using ECAM. In addition to the development work carried out under this task, ECAM v2.0 also incorporates a sub-menu "PNNL Retuning" with several other useful EBCx-related charts. This sub-menu was already incorporated into a separate version of ECAM developed for the Pacific Northwest National Laboratory's Retuning program[15], but was not part of the version publicly available from the CCC's website.

Figure 2: Example ECAM charts



Source: California Commissioning Collaborative. © 2012

15 More details at http://buildingefficiency.labworks.org/small.stm

ECAM v2.0 is posted on a newly-designed CCC web page[16], and is accompanied by a comprehensive User Guide and ten web-based video tutorials of between two and seven minutes duration.

3.3 Custom Building Optimization Analysis (C-BOA) Tool

C-BOA[17] is an all-new Microsoft Excel-based tool that can calculate savings for the following nine EBCx measures:

- Optimize Economizer Performance.
- Optimize Air Handler Scheduling.
- Optimize or Reset Supply Air Temperature.
- Reduce or Reset Discharge Static Pressure Setpoint.
- Add or Optimize VFD on Supply Fan.
- Add or Optimize VFD on Chilled Water Pump.
- Optimize or Reset Chilled Water Supply Temperature.
- Optimize or Reset Condenser Water Supply Temperature.
- Add or Optimize VFD on Cooling Tower Fans.

Based on data from past utility EBCx projects in California, this list of measures is the most common, and provides highest savings, of all HVAC-related measures. The C-BOA tool is a follow on from the CCC's Pump and Fan Workbooks, which were developed with PIER funding and released in 2008; these two workbooks are high quality savings calculation tools that can handle a high degree of building/system complexity. While considered robust and comprehensive, their complexity is thought to restrict their use to more experienced EBCx providers – C-BOA was developed to suit more general use, while still accommodating a good degree of complexity in building design and HVAC system configuration.

C-BOA development overlapped with development of the Building Optimization Analysis (BOA) Tool, which was released in 2011[18]. BOA savings calculations are based on simulated parametric runs as opposed to C-BOA which employs spreadsheet calculations. BOA has a relatively limited number of data inputs compared with C-BOA, and so does not provide the same level of customization. The C-BOA development team intentionally named its tool in a way that connects it with the BOA tool, as they are considered complementary - BOA is a valuable tool for simple and/or low-savings measures, and C-BOA can be used when greater flexibility is required.

C-BOA was developed as a standalone Excel file, with embedded macros driving the savings calculations. Figure 3 shows a typical data input tab for C-BOA. Development was iterative, starting with detailed specification development and then passing through multiple

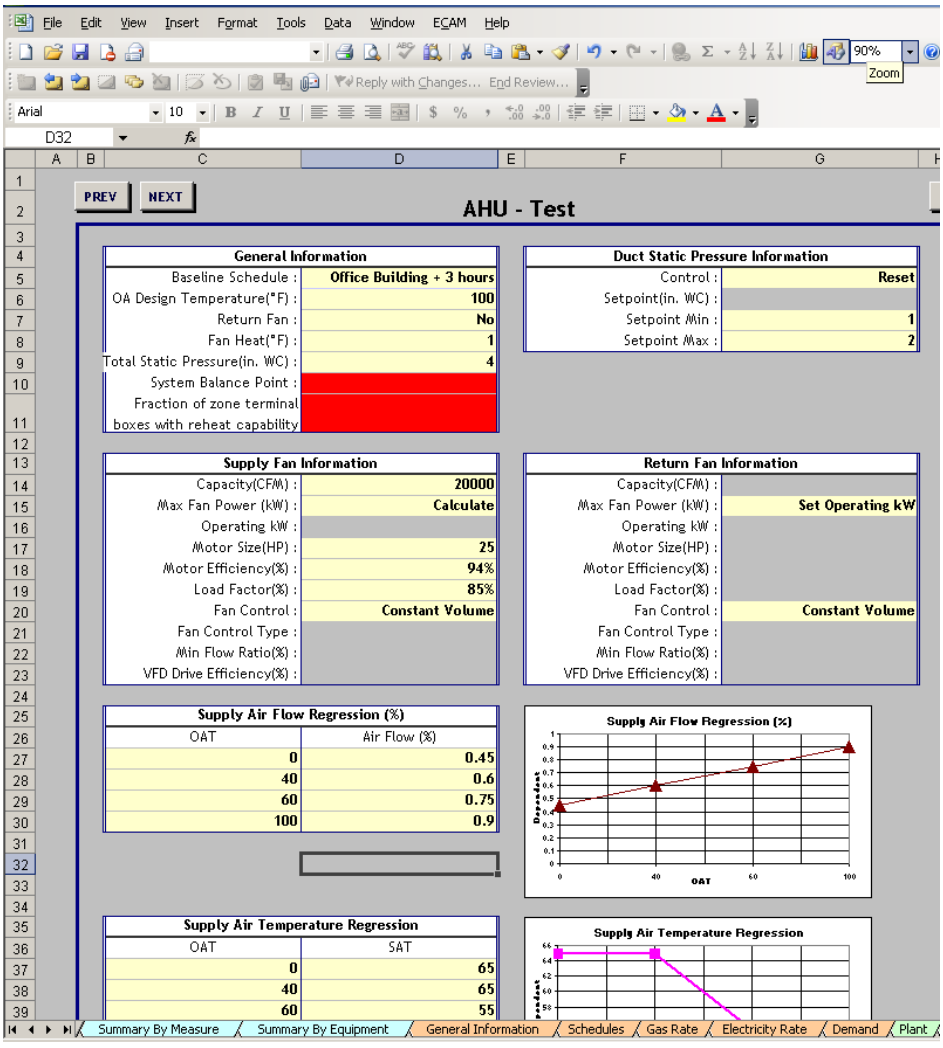
16 See http://cacx.org/PIER/ecam/ for details.

17 See http://www.cacx.org/resources/rcxtools/cboa/index.html for details.

18 See http://cacx.org/resources/rcxtools/spreadsheet_tools.html#energy_savings_calculation_tools for details.

development/test/review cycles. Tool testing was done by recalculating savings from past EBCx projects and comparing results with the original savings calculations. In addition, measure-by-measure savings from California's major utility programs between 2006-and 2009 were analyzed to establish an expected range of values for each measure type, and this data was compared to C-BOA savings estimates. Both of these comparison methods are imperfect, as they compare one tool's estimates with another's; however, given the limited task budget the development team considered this a reasonable approach for establishing confidence in C-BOA's calculation accuracy. Results of this testing are summarized in the report *C-BOA Tool: Validation of Energy Savings Estimation Methods*.[19]

Figure 3: A Typical Data Input Tab for the C-BOA Savings Calculation Tool



Source: California Commissioning Collaborative. © 2012

19 Report can be downloaded at: http://cacx.org/resources/rcxtools/cboa/C-BOA_Energy_Savings_Validation.pdf

In addition to validating C-BOA's savings calculations, a separate report documents the tool's demand reduction calculation methodology - California's utility programs are required to calculate demand savings based on the Database for Energy Efficient Resources (DEER) methodologies. The resulting report, *C-BOA Tool: Comparison of Peak Demand Savings Estimation Methods*,[20] recommended that C-BOA be allowed for use in determining peak demand savings for EBCx projects.

3.4 EBCx Tools: Outreach

The primary target audiences for the tools developed under this task were the EBCx providers who would use them and the utility program managers who might recommend or require their use in programs. A secondary audience was the third parties contracted by utilities to review EBCx provider deliverables, where applicable.

The research team conducted outreach via conference/meeting presentations, online media, and direct outreach to utility program managers. Conference/meeting presentations included:

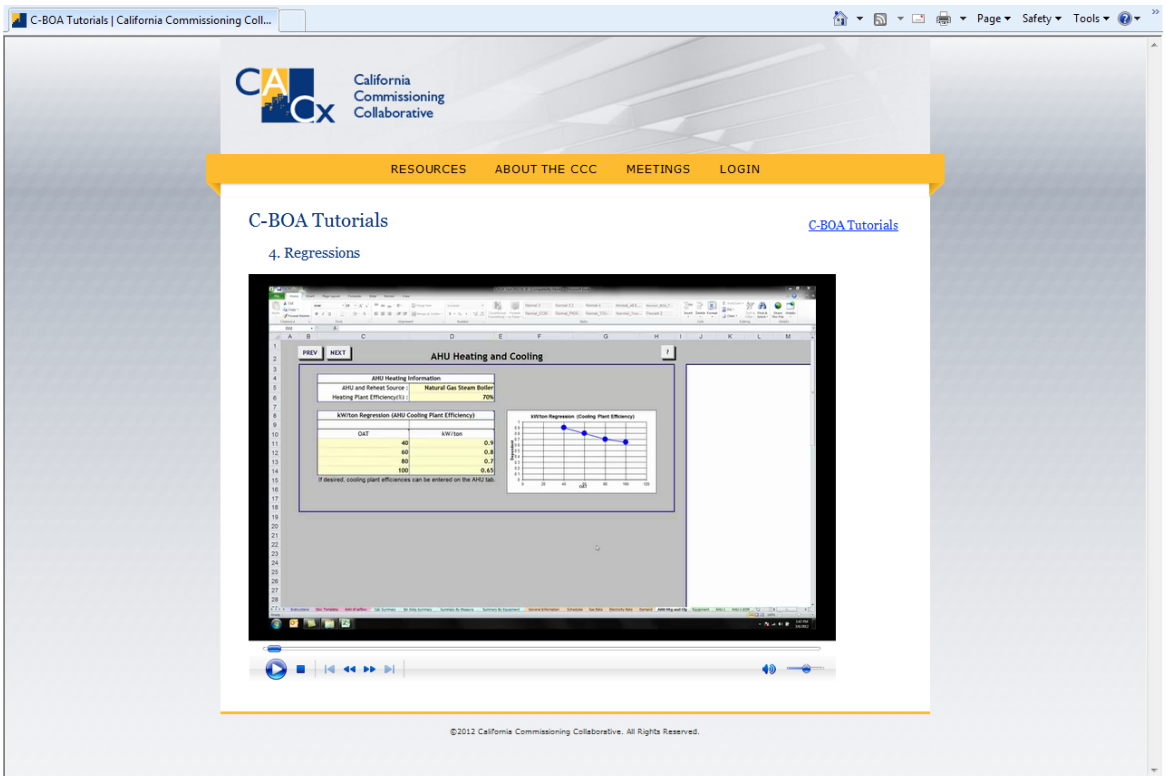
- The National Conference on Building Commissioning, 2011
- ASHRAE Technical Committee on Commissioning, Summer meeting, August 2012
- CCC meetings: the status of this project was presented at every CCC meeting from contract start in 2009 through to June 2012

Development of web-based tutorials was a key element of the outreach strategy. While conference presentations and workshops can be a useful venue for reaching industry leaders they are a one-time event. In developing web-based tutorials for both ECAM v2.0 and C-BOA, the research team has developed a training resource that is available on demand. These tutorials cover elements of the tools' functionality from basic start-up tasks to more advanced features.

Figure 4 shows a screenshot of one of the tutorials.

20 Report can be downloaded at:
http://cacx.org/resources/rcxtools/cboa/C-BOA_Peak_Demand_Comparison.pdf

Figure 4: Screenshot of web-based tutorial for ECAM v2.0



Source: California Commissioning Collaborative. © 2012

Eleven tutorials were developed for C-BOA, and ten for ECAM v2.0, of between three and seven minutes duration. The benefits of these tutorials, in comparison with a one-time workshop, are (1) they are available on demand, indefinitely, and (2) they break the tool's features into short duration tutorials, meaning that users can tailor their training to the functions they will use and the time they have available.

To support outreach efforts, the C-BOA development team held two web-based meetings with California utility EBCx program managers. Key features of the tool were demonstrated, along with an explanation of the development process and technical approach. At the time of these meetings, the utility programs were nearing the end of their program cycle, and so few projects were at the early stage of needing energy savings calculations. CCC will continue to work with utilities to promote the use of C-BOA and ECAM v2.0 as utility programs enter the transition period in 2013 and subsequently scale up for the next full program cycle in 2015.

ECAM v2.0 and C-BOA were promoted via announcements within 16 LinkedIn® groups, and also via Twitter®.

3.5 EBCx Tools: Conclusions and Next Steps

ECAM v2.0 development met expectations, and C-BOA exceeded expectations, owing to the additional match funding which resulted in the tool covering nine measures rather than the original scope of six measures. The development of web-based video tutorials was a new type

of offering from the CCC which has strong potential as a training tool; CCC will monitor the effectiveness of the videos based on EBCx provider feedback.

As of August 31, 2012, ECAM v2.0 had been downloaded 394 times, and C-BOA had been downloaded 716 times. For C-BOA this is a very encouraging result, considering that it was released in February 2012, many months later than ECAM v2.0. As mentioned earlier, California's current utility program cycle is ending in December 2012, with a new cycle starting in 2013. CCC staff will continue working with EBCx utility program managers to encourage adoption of both of these new tools within programs.

In order to support market adoption of ECAM v2.0 and C-BOA, it is recommended that ongoing user support be provided. CCC is well-placed to provide email/phone support through its own staff or via subcontracting with the developers of the two tools, budget permitting. In the absence of formal support, users groups have been setup on LinkedIn, whereby users could provide support to each other; this option negates the need for CCC budget but relies on the cooperation of users. CCC will review options for 2013, and will monitor activities on the LinkedIn user groups.

While C-BOA can be a very effective tool in its current state, covering a high proportion of the measures that are found in California EBCx projects, there are two potential directions for broadening its application further:

- Adding more measures; the natural next step would be to add measures covering heating hot water and domestic hot water (which would primarily save natural gas).
- Adding applicability for projects outside of California (Currently, C-BOA is pre-loaded with climate data for all of California's climate zones, which cannot be user-modified).

There has been minimal user feedback on ECAM v2.0 and C-BOA to date, and this task did not cover such data collection or pilots. CCC staff will continue to promote these new tools as the next utility program cycle starts ramping up in 2013.

CHAPTER 4:
Improving the Persistence of EBCx Benefits

The goal of this task was to identify key barriers to the adoption of energy savings persistence strategies and collect information on factors that cause degradation of the savings from EBCx measures. The research team conducted research focusing on the key managerial, organizational, financial, and technological factors that lead to best-in-class examples. Findings from the research were used to develop a research report, best practice case studies, and a best practice handbook for building owners, managers, and operators.

4.1 Research & Development Approach

This task employed a wide range of research and development methods, including primary research interviews, site visits, literature review, vendor surveys, and creation of high quality publications. The research is documented in detail in the following three research reports:

- *Investigating Energy Performance Tracking Strategies in the Market*.[21] A literature review of 20 documents, 21 phone interviews with building owners and staff, and detailed on-site interviews at 5 buildings. This report gathered perspectives on what constitutes best practice in energy performance tracking and what factors contribute to energy performance degradation.
- *Characterization of Fault Detection and Diagnostic (FDD) and Advanced Energy Information System (EIS) Tools*.[22] This research evaluated and characterized nine building performance tracking tools, with a focus on FDD tools. Research was a combination of reviewing vendor-published literature on the tools, and interviews with tool vendors and users.
- *Characterization of Building Performance Metrics Tracking Methodologies*.[23] This literature review evaluated 80 works, and included a detailed review of 23. In addition, interviews were conducted with seven individuals including performance contractors, controls contractors, a software developer, and an EIS business development team. The purpose of this research was to investigate building performance metrics that can be used by building owners, energy managers, and operators to track the performance of commercial facilities.

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21 Friedman, Hannah, Mark Effinger, Dave Moser (PECI). 2010. *Investigating Energy Performance Tracking Strategies in the Market.* California Commissioning Collaborative. Available at http://www.cacx.org/PIER/documents/Subtask_4-2_Report.pdf

22 Ulickey, Joy, Tim Fackler, Eric Koeppel, Jonathan Soper (Enovity, Inc.). 2010. *Characterization of Fault Detection and Diagnostic (FDD) and Advanced Energy Information System (EIS) Tools.* California Commissioning Collaborative. Available at http://www.cacx.org/PIER/documents/Subtask_4-3_Report.pdf

23 Greensfelder, Erik, Hannah Friedman, Eliot Crowe (PECI). 2010. *Characterization of Building Performance Metrics Tracking Methodologies.* California Commissioning Collaborative. Available at http://www.cacx.org/PIER/documents/Subtask_4-4_Report.pdf

Development of the best practice handbook was iterative, involving multiple cycles of development and review. The research team's research indicated that building performance tracking as a discipline was not formalized, and while useful tools were emerging there was little indication of wide market adoption. The team therefore determined that the handbook would provide the greatest benefit if focused on building performance tracking in general as opposed to having a narrow focus on maintaining the benefits from EBCx projects specifically. The team believed that a general handbook could benefit any building owner and not be restricted to those who had completed EBCx projects.

A considerable amount of the team's effort went into developing both the structure of the handbook and a few high-impact graphics that could illustrate building performance tracking fundamentals; the graphics were considered valuable not only for the handbook itself but also for inclusion in outreach materials.

4.2 Summary of Research Findings

Detailed research findings from this task are presented in the research reports listed in the prior section, and summaries are presented below.

4.2.1 Investigating Energy Performance Tracking Strategies in the Market

The team found that performance tracking tools and methods are not widely used or well-understood. End-users typically underutilize the capability of their system, and education regarding the various types of strategies and available tools is generally lacking. The limited information that is available is focused on technical capabilities of the tools, and not on how end-users can effectively use the tools. Although some information is available on tool capabilities, there is no commonly understood and accepted framework for categorizing the landscape of energy performance tracking tools.

4.2.2 Characterization of FDD and Advanced EIS Tools

Obtaining information for this research was more difficult than originally anticipated. The number of tools actually deployed and in use was more severely limited than initially thought. The internet, trade magazines and others within the industry were consulted in an effort to obtain as much information as possible. Ultimately, it was found that many of the products were either newly developed or still in testing phases. However, given the number of tools in circulation, nine toolsets were characterized encompassing both system management and energy tracking approaches as well as single and multi-system fault detection (and in rare cases, diagnostic) tools.

4.2.3 Characterization of Building Performance Metrics Tracking Methodologies

While there is some literature providing recommendations on selection of key performance metrics, there was little evidence provided that tracking metrics is common practice. The research team developed a matrix of recommended performance metrics under the following four headings:

- **Basic Energy Metrics:** Metrics that use whole building utility meter data. These metrics are relatively easy to track, and are recommended for all buildings

- **Advanced Energy Metrics:** Metrics that use whole building utility meter data but require more advanced analysis than basic energy metrics; or metrics that require additional meters beyond whole building energy use meters.
- **Basic System Metrics:** Metrics that use existing points from the building automation system (BAS) or maintenance management system. These metrics are relatively easy to track.
- **Advanced System Metrics:** Metrics that require additional points to be added to the BAS or maintenance management system. This category also includes metrics that use both meter data and BAS data in combination.

4.3 The Building Performance Tracking Handbook and Case Studies

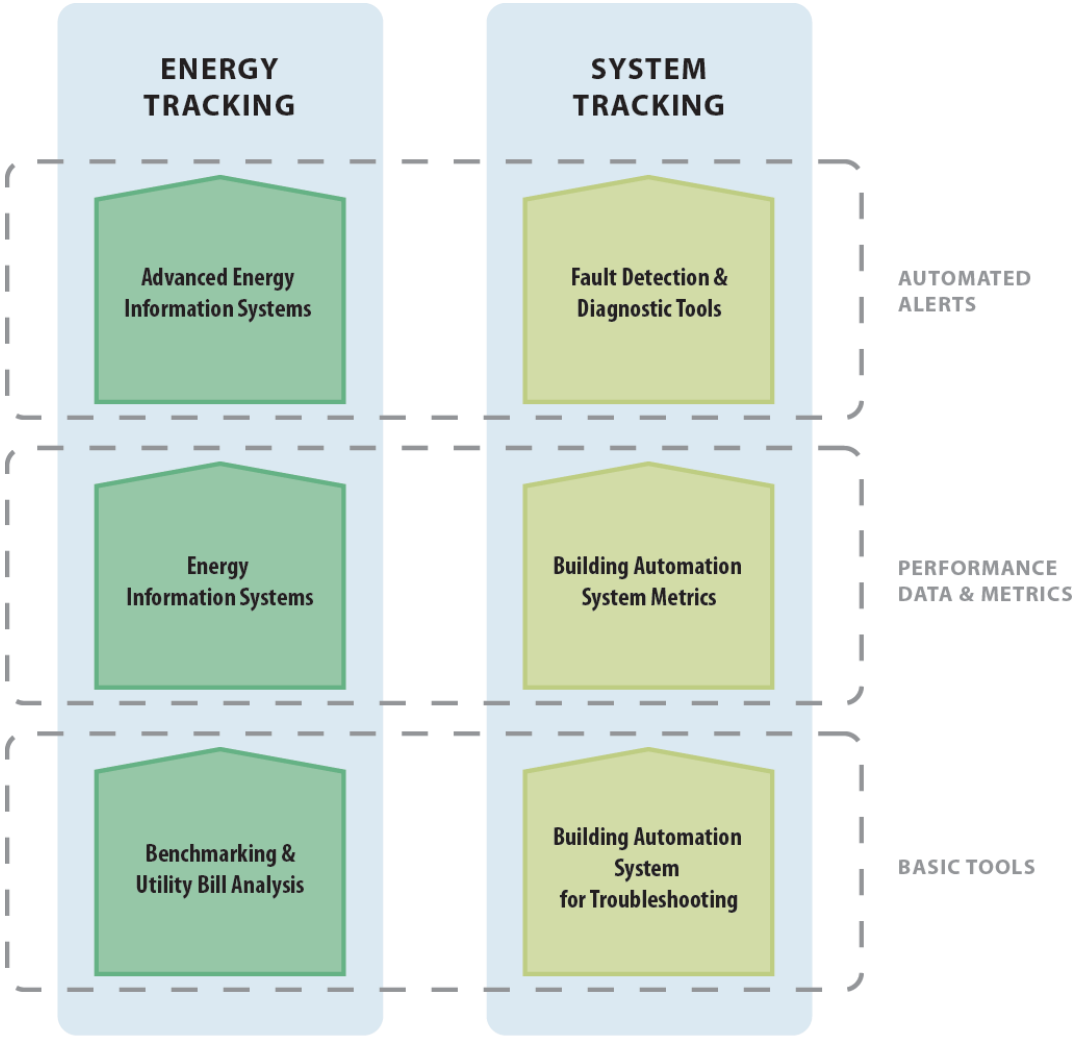
The *Building Performance Tracking Handbook*[24] was developed primarily for property managers, energy managers, and facility engineers; it may also benefit facility service contractors and building operators. This 79-page Handbook covers the fundamentals of building performance tracking, including management aspects as well as describing the range of tools available. The Handbook is broken down into four main sections:

- **Introduction to Building Performance Tracking:** What it is, and how it relates to commissioning; making the business case for building performance tracking.
- **The Basics of Building Performance Tracking:** Steps to building a successful management framework for building performance tracking; energy benchmarking, utility bill analysis, building automation systems.
- **Beyond the Basics:** Energy tracking with Energy Information Systems; tracking key system performance metrics; fault detection and diagnostic tools.
- **What's Next?:** Selecting a performance tracking approach; useful resources

Figure 5 is an example of one of the graphics developed for inclusion in the Handbook, describing the six building performance tracking approaches. One of the challenges identified by the research team was that there are an ever-increasing number of tools available but there was no easy way to classify their functionality and compare them. The goal in developing this graphic was to have a framework for assessing any performance tracking tool.

24 Friedman, Hannah, Eliot Crowe, Emilia Sibley, Mark Effinger (PECI). 2011. *Building Performance Tracking Handbook*. California Commissioning Collaborative. Available at http://www.cacx.org/PIER/handbook.html

Figure 5: Graphic Describing the Six Building Performance Tracking Approaches



Source: California Commissioning Collaborative. © 2012

It is often stated anecdotally that building owners and managers are strongly influenced by the practices of their peers. The research team therefore sought endorsement of the Handbook by the Building Owners and Managers Association (BOMA). A final draft of the Handbook was sent to the chair of BOMA California's Energy Committee for review, and following a few minor edits the Handbook received a signed endorsement letter which is incorporated into the Handbook. The research team also used quotes from building owners, managers, and engineers throughout the Handbook to highlight key points; these quotes were drawn from the interviews carried out under this task, and used with the interviewees' written permission.

To accompany the Handbook, the research team developed four 2-page case studies[25] that highlighted best practice examples for both commercial and institutional buildings. Each case

25 Case studies available at http://cacx.org/PIER/handbook.html

study shares the same formatting and some fundamental recommendations from the Handbook, along with examples of successful applications of building performance tracking.

500 copies of the Building Performance Tracking Handbook were printed, along with posting an online version on a newly-design web page. Requests for hard copies have been received through conference presentations, CCC meetings, and via people browsing the CCC's website. CCC staff will continue to seek opportunities to distribute the Handbook through meetings and presentations. Case studies are presented online-only, on the same page as the Handbook.

4.4 EBCx Savings Persistence: Outreach

Outreach for this task included dissemination of the research findings through conference presentations and a range of publicity for the Building Performance Tracking Handbook and associated case studies.

In addition to presenting research findings at several CCC in-person meetings, presentations were made at:

- The National Conference on Building Commissioning (NCBC), May 2010
- EPA webinar on ongoing commissioning, August 2010
- Consortium for Energy Efficiency (CEE) meeting, September 2010

The CEE meeting was particularly timely, as it came at a time when the nationwide utility participants in that group were looking for clarity on how monitoring could be integrated into utility programs. The framework shown in Figure 5 was part of a presentation to the Consortium for Energy Efficiency who has adopted and shared it with member utilities across the US. The Principal Investigator leading this task has continued constructive dialog with CEE on this topic.
The research team developed a generic article promoting the Handbook and case studies. The article, along with a press release was distributed to over 300 publications in California (online and print publications). The article or press release featured in 26 online articles – for example an article was placed on the homepage of Environmental Leader, which receives over 150,000 visitors per month.

In addition to online articles, one print article was written for Buildings magazine. This magazine has over 74,000 subscribers who are responsible for over 4.5 million buildings nationwide.

CCC has informally promoted the Handbook regularly to California's utility program managers as a tool to help promote persistence of energy savings. In some cases the Handbook has been handed out to EBCx program participants by field staff.

As of August 31, 2012, the Handbook had been downloaded 1,661 times, and 141 hard copies had been distributed; the case studies had been downloaded a total of 136 times

4.5 EBCx Savings Persistence: Conclusions and Next Steps

The research, development, and outreach for this task were considered successful. Research on the topic of building performance tracking and measure persistence was found to be very limited, and so the primary research and collation of existing literature provides a solid baseline for future research on this very relevant topic. The research was also crucial in shaping the Handbook and case studies developed under this task.

At the time of writing this report, the Building Performance Tracking Handbook is approximately 18 months old. While the market for building performance tracking software has seen a proliferation of products during that time period, the research team considers the content of the Handbook to be as relevant now as when it was first published.

While there has been significant growth in the number of building performance tracking options, there is no evidence that market penetration is high. Integration of building performance tracking tools into utility programs is a recommended next step, to support recruitment, measure identification, measurement & verification (M&V), and persistence of savings.

In order to accomplish utility program integration, one critical area of research is to establish requirements for using monitoring tools to verify programmatic energy savings. Some potential research questions include:

- How long / how much data is required to establish reliable baseline and post-implementation energy use calculations?
- How does seasonality affect data collection requirements?
- What are acceptable levels of accuracy for tools to be used for energy savings verification?
- What is the minimum level of savings that can be identified reliably by tools?

Other recommended research relating to utility program applications include looking at the impacts of monitoring on persistence of savings, and evaluating the behavior-driven savings from implementing monitoring in the absence of a formal energy-saving retrofit or EBCx project.

A final recommendation is to conduct a training needs assessment for building owners, managers, and operators to determine the type and extent of training and other support needed to enable successful implementation of monitoring systems.

CHAPTER 5:
Verification of Savings from Existing Building Commissioning

The goal of this task was to help resolve technical barriers to implementing effective EBCx savings verification strategies, including:

- Lack of specific industry-accepted methodologies for measuring and verifying energy savings in EBCx projects.
- Absence of practical guidelines for selecting and applying different methodologies.

In 2008 the California Commissioning Collaborative released the *Guidelines for Verifying Existing Building Commissioning Project Savings, Using Interval Data Energy Models (IPMVP), Options B and C*[26], (Option B/C Guidelines) to promote the use of energy meter data for verifying savings from EBCx projects. The methodology presented in the Option B/C Guidelines was adapted from the International Performance Measurement and Verification Protocol (IPMVP), which is established in the energy services company (ESCO) industry as well as the utility program evaluation community. The Option B/C Guidelines sought to (1) streamline the verification methods to suit use within utility programs, and (2) tailor the guidance to the specific needs relating to EBCx projects (as opposed equipment replacements).

Since the release of the Option B/C Guidelines there has been no tracking of the adoption of the method, nor any research into the ability of typical EBCx providers to apply the guidelines in practice. Part of this task was concerned with assessing the latter, through a small-scale pilot of the Option B/C Guidelines involving two EBCx providers.

In addition to assessing and improving the Option B/C Guidelines, this project sought to add further verification methods so that EBCx program managers and EBCx providers would have a range of verification options available, along with a means for determining the most suitable method for a given project.

5.1 Research & Development Approach

The option B/C Guidelines were assessed via a small-scale pilot and review of the guidelines by two EBCx providers; this research was designed to provide qualitative feedback in a relatively short space of time and with limited budget.

Development of new guidelines was a team activity that went through multiple iterative cycles, with a TAG performing external peer review. Research & development is described in detail below.

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26 Jump, David (Quantum Energy Services & Technologies). 2008. *Guidelines for Verifying Existing Building Commissioning Project Savings Using Interval Data Energy Models: IPMVP Options B and C.* California Commissioning Collaborative. http://resources.cacx.org/library/holdings/VoS%20Guide%20111308_final.pdf

5.1.1 Option B/C Guidelines Assessment

The goals of the pilot assessment were to implement the Option B/C methodology using interval data on two projects that were currently being implemented under a utility EBCx program. The EBCx service providers engaged for this activity were to provide feedback on the clarity and effectiveness of the guideline, as well as provide the verified project results for a case study. This plan also intended to familiarize EBCx program managers with the methodology so that they would be aware of the method and its benefits. The three outcomes of the Option B/C pilot were:

- Recommendations for improvements to the Option B/C guideline that could be incorporated into an updated version.
- Two case studies that could be used to help EBCx providers implement the method described in the guideline.
- A pilot summary report, outlining the activities and findings from the pilots.

In practice, the pilots followed an iterative approach, whereby the task Principal Investigator (the author of the Option B/C Guidelines) coordinated with each EBCx provider as they worked through the steps of the verification process. This ongoing coordination was required in order to confirm regression methodologies, assist with application of tools to support the process, and to clarify elements of the Option B/C Guidelines.

Research findings from the pilot of the Option B/C Guidelines were compiled in a summary report[27].

5.1.2 Verification of Savings Guidelines

New verification of savings guidelines were developed by the Principal Investigator along with two subcontractors, each focusing on creating content for different sections. The research team's early efforts focused on defining the four methods that would feature in the new guidelines and in determining the guidelines' structure. An outline was created for the new guidelines, and then iterative versions of drafts were developed and peer reviewed; one of the key roles of the task TAG was to review the guidelines at various stages and provide constructive input. Once completed, the new guidelines were sent to a technical editor for review and formatting. The new guidelines were formatted for web-posting.

Feedback from the Option B/C pilot participants was used to improve the new guidelines; both pilot participants provided feedback that the previous guidelines did not provide very specific guidance on implementing the interval-data energy modeling method. In particular, they wanted to see more step-by-step descriptions of how to develop M&V plans, and guidance on how to determine whether Option B or C would be best for a given project. In response to this feedback, more specific guidance was developed that described how to first assess a whole building approach for verifying savings, then proceeding to a more detailed retrofit isolation

27 Jump, David (Quantum Energy Services and Technologies). 2012. *Summary Report from Pilots of "Option B/C" Verification Method*. California Commissioning Collaborative.

approach when needed. A flowchart describing this process was developed and specific step-by-step procedures were included in the new guidelines.

Other comments were editorial in nature and included reducing the amount of text in many sections and moving non-core information, such as data preparation, and development of proxy variables, to an appendix of the new guidelines.

5.2 The Verification of Savings Guidelines and Case Studies

The primary deliverable for this task was the *Guidelines for Verifying Savings from Commissioning Existing Buildings*[28] (Guidelines). These Guidelines provide standardized methods that may be used within EBCx projects to calculate and verify energy savings. They also provide a framework for EBCx providers to select a method based on a project's goals, resources, and constraints. These Guidelines define the technical requirements and analysis procedures for each method, define common terminology, identify useful tools, and provide examples.

The Guidelines cover four methods for verifying savings, providing practical guidance for their application. Additionally there is guidance around how to select the appropriate method for a given project, how each method aligns with formal IPMVP and ASHRAE M&V guidelines, and general information on how M&V fits into the EBCx process. The four methods defined in the Guidelines are:

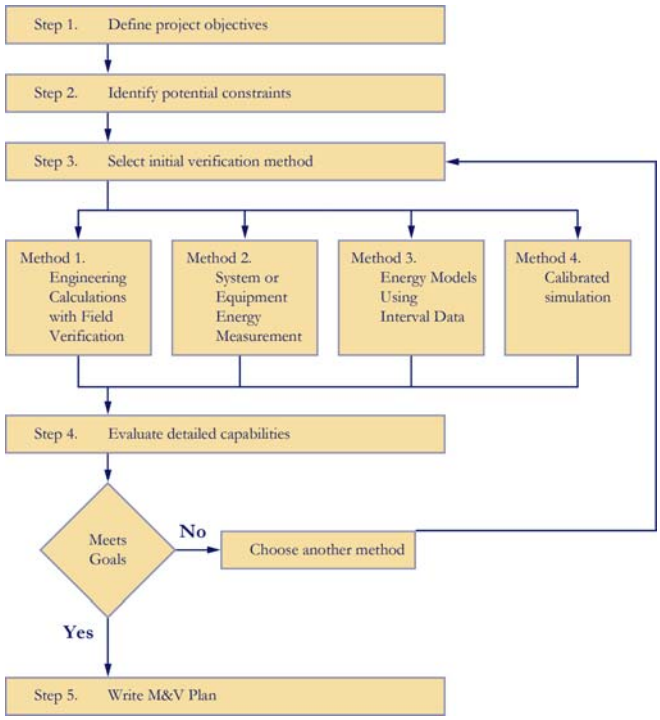
- **Method 1: Engineering Calculations with Field Verification** describes how engineering calculations used to estimate savings prior to implementation are subsequently used to verify actual savings. It also describes how post-installation measurements used are used to improve the savings estimates.
- **Method 2: System or Equipment Energy Measurement** characterizes the system or equipment energy use by its load and schedule components so that each component is measured separately. The primary impact of the EBCx measures on each component is used to determine post-installation measurements. This method is based on retrofit isolation approaches defined by IPMVP and ASHRAE Guideline 14-2002.
- **Method 3: Energy Models Using Interval Data** describes a verification method in which empirical models of baseline energy use and key independent variables are used to verify savings. It can be used to verify total savings in a whole building or for building subsystems. This M&V methodology may be applied in adherence with IPMVP's Option C Whole Building, or Option B Retrofit Isolation approaches. Method 3 may also be applied in compliance with ASHRAE Guideline 14-2002 Whole Building performance path.
- **Method 4: Calibrated Simulation** describes the use of whole-building simulation software to develop and calibrate a building model that correctly reproduces the

28 Jump, David (Quantum Energy Services & Technologies), Lia Webster, Mark Effinger (PECI), Greg Risko (Architectural Energy Corporation). 2012. *Guidelines for Verifying Savings from Commissioning Existing Buildings.* California Commissioning Collaborative. http://www.cacx.org/resources/vos-guidelines/

baseline energy use of a building and its subsystems. This simulation may then be used to model the resultant energy savings from a set of implemented measures. This method may be applied in adherence with IPMVP's Option D, or ASHRAE Guideline 14-2002.

The Option B/C Guidelines have been absorbed into Method 3 of the new Guidelines (the term "Option B/C method" has been superseded by Method 3). The new Guidelines, 92 pages plus appendices, provide overview information, guidance on selecting the most appropriate method for a given project, and step by step guidance on applying each of the four methods. Figure 6 is an example of a flow chart from the Guidelines; in this case, the flow chart illustrates how to select an appropriate verification method for a given project.

Figure 6: Process Flow Chart for Selecting a Savings Verification Method



Source: California Commissioning Collaborative. © 2012

To accompany the new Guidelines, two case studies have been developed for Method 3 (formerly Option B/C). These case studies, based on actual projects, help to clarify the situations in which Method 3 is an ideal choice, and to explain the method using real data. These case studies will be posted online alongside the new Guidelines.

5.3 Verification of EBCx Savings: Outreach

The new Guidelines were posted on a newly-created web page, and the Method 3 case studies will be posted on the same page when ready for release. Upon release, the new Guidelines were promoted via an announcement on 16 LinkedIn groups.

Development, and subsequent release, of the new Guidelines was publicized via presentations at numerous CCC meetings, and also at the National Conference on Building Commissioning in August 2011. The task Principal Investigator also presented the new Guidelines at a 2012 meeting of the CEE, a group of national utility program managers.

Between August and September 2012, the research team presented a series of four one-hour webinars on the new Guidelines. The webinar series provided an outline of the guideline and described each of the methods. 244 registrants signed up for the webinars, and following completion of the series the presentations were posted to the same web page as the new Guidelines.

As of the end of August 2012, the Guidelines had been downloaded 641 times.

5.4 Verification of EBCx Savings: Conclusions and Next Steps

The release of the Guidelines for Verifying Savings from Commissioning Existing Buildings can help to address a significant market barrier for EBCx. Lack of standardization in verifying savings places a high labor burden on quality control for utilities in reviewing EBCx provider deliverables; this in turn affects project and program cost-effectiveness. It is too soon to evaluate the effectiveness of the new Guidelines, but the CCC will continue to promote them and to coordinate with California's utility program managers in supporting market adoption.

The research team recommends conducting a training needs assessment of EBCx providers to determine M&V skills required to implement the methods described in the guideline. This could be used to inform development of training materials that would support use of the new Guidelines.

Supporting integration of building performance tracking tools into utility programs was one of the recommendations under Task 4; this overlaps onto this task also. The new Guidelines and the lessons learned from the Option B/C pilots could be helpful in developing a methodology for validating the capability of monitoring systems to verify savings. This in turn could help facilitate whole-building approaches for energy efficiency programs, incorporating operational improvements, retrofits, and behavior-based approaches. There are many research questions that would need to be resolved in order to support whole-building programs, some of which were listed at the end of Chapter 4. Other questions include:

- How can savings verification methods consistently and accurately account for changes unrelated to the energy efficiency project, such as occupancy changes (also known as non-routine adjustments)?
- When considering combining operational, retrofit, and behavioral approaches to improving energy efficiency, how can utilities determine the effective useful life of the savings?

CHAPTER 6:
Title 24, Part 6 Acceptance Testing: Enforcement and Effectiveness

The goal of this task was to evaluate Title 24 building code[29] acceptance testing requirements and enforcement procedures to gain an in-depth understanding of the challenges, limitations, and opportunities for achieving the intended energy efficiency. The research encompassed two separate but related sub-tasks:

- Interviews with building permitting officials, acceptance testing contractors, design engineers, and building owners to determine current enforcement procedures and barriers to compliance.
- Field work with mechanical contractors to evaluate the effectiveness of acceptance testing documentation.

The product of this research was a set of recommendations for changes to the Title 24 acceptance testing forms, enforcement procedures, and for training and outreach. The research conducted under this task is detailed in the report *Evaluation of Title 24 Acceptance Testing Enforcement and Effectiveness*.[30] Research methodology and results are detailed in that report, and are summarized here.

Following conclusion of the research phase, three new documents were created to help improve compliance with Title 24 acceptance testing requirements:

- A single-page infographic describing the steps in the acceptance testing process.
- A 'bid sheet' to be used by contractors when preparing bids that include acceptance testing.
- A contractor case study relating to acceptance testing.

Printed outreach materials have been distributed to several industry organizations in California having an interest in promoting increased building code compliance.

6.1 Research & Development Approach

There are many actors involved in the acceptance testing process, and across California there are hundreds of building departments issuing permits dependent upon meeting complex building requirements. Given this complexity, a comprehensive quantitative study to assess

29 Title 24 is California's building code, with Part 6 covering energy efficiency. A compliance manual defines requirements for testing equipment to verify performance, and is accompanied by a series of testing forms. All references to Title 24 in this report relate to Part 6. See http://www.energy.ca.gov/title24/ for more details.

30 Tyler, Matthew, John Farley, Eliot Crowe (PECI). 2011. *Evaluation of Title 24 Acceptance Testing Enforcement and Effectiveness.* California Commissioning Collaborative. Available at http://www.cacx.org/PIER/documents/T24_Acceptance_Testing_Final_Report.pdf

enforcement procedures and compliance with acceptance testing requirements would be lengthy and expensive. This research instead took a qualitative approach using small sample sizes, interviewing a variety of stakeholders, and performing field tests.

6.1.1 Assessing Enforcement Procedures

The research team conducted a total of 31 phone interviews with stakeholders, including building officials, testing contractors, design engineers, and building owners. In addition, researchers visited several building departments for a first-hand view of their processes. Interview candidates were selected based on the existing contacts of research team members and consultation with CEC staff members. In some cases interview candidates were chosen as they were known to represent building departments with good enforcement procedures, but in most cases enforcement procedures were not known.

Phone interviews lasted approximately 60 minutes, and in-person interviews lasted approximately 90 minutes. The research team developed an interview guide, and used this to guide a flexible interviewing approach whereby the interviewer emphasized questions most relevant to the interviewee's experience and priority. Upon completion of all interviews, responses were briefly summarized in a matrix format, which appears as an appendix to the task research report.

6.1.2 Field Testing to Assess Effectiveness of Acceptance Testing Requirements

To determine the effectiveness of the acceptance test procedures, eight different contractors were enlisted to perform multiple acceptance tests at 13 commercial high-rise and low-rise buildings. The researchers observed and recorded the actual procedures used in the resulting 48 acceptance tests. A comparison of the observed procedures with the specified Title 24 procedures and feedback from the contractors yielded the following conclusions:

- Most contractors are at least somewhat familiar with the tests. However, the field testing indicated that often their perceived level of understanding exceeded their actual ability to perform the specified tests.
- Contractors are not aware of reference materials such as the Compliance Manual.
- Confusion arises in interpretation of the procedures, as the tests are complex and the forms are sometimes unclear.
- Contractor training is insufficient. Approximately half of the tests could not be performed without a moderate or substantial level of coaching.

The research team selected buildings for field tests with the help of interested building owners. Candidate building owners were suggested by building departments and contractors, or identified through their previous participation in EBCx programs and research projects. Owners who were familiar with acceptance tests were often willing to participate in this study because the tests represented a free evaluation of their HVAC and lighting systems.

The 13 buildings selected for the project had diverse characteristics. Though they were not a fully representative sample of the State's buildings, they did include many of the common systems that are subject to acceptance testing. They represented two climate zones, two compliance jurisdictions, a variety of equipment, and a corresponding variety of testing

opportunities. Some were built before the 2008 Title 24 acceptance testing provisions were in effect and others were built subject to those provisions. It was desirable if the building had undergone previous acceptance testing prior to occupancy, but it was not a requirement.

6.2 Research Findings

The interviews and field evaluation work resulted in a number of qualitative findings indicating barriers to enforcement of acceptance requirements and barriers that prevent contractors from effectively performing acceptance tests. Barriers to enforcement are generally more complex, as they relate to interactions between multiple stakeholders with different priorities and responsibilities relating to acceptance testing requirements. Barriers to successful implementation of tests are more straightforward to address, and in some cases may be resolved through simple updates to test forms. The key findings are summarized below.

6.2.1 Assessing Enforcement Procedures

Building department phone interviews and site visits produced several key findings:

- Building departments are underfunded and understaffed, thus acceptance forms receive little review, and plans examinations are often outsourced to local engineering firms.
- Building departments and the firms they employ need an improved understanding of the testing procedures and the methods for reviewing test forms. More importantly, they need successful models of enforcement that illustrate practical approaches for improving compliance.
- The "Responsible Party" is very often not specified on the forms. Thus, it is unclear who is responsible to execute tests, which can contribute to omission of the tests.

It was noted that the Energy Commission website provides a comprehensive resource of support documentation, helpful checklists for building department reviewers, and short video tutorials. In addition, the California Commissioning Collaborative (with funding from the Energy Commission) has developed a hands-on training workshop curriculum for building departments. This indicates that any lack of understanding of requirements among building departments is not simply due to lack of training opportunities and resources.

6.2.2 Field Testing to Assess Effectiveness of Acceptance Testing Requirements

A comparison of the observed tests with the specified Title 24 acceptance testing requirements, and feedback from the contractors yielded the following conclusions:

- Most contractors are at least somewhat familiar with the tests. However, the field testing indicated that often their perceived level of understanding exceeded their actual ability to perform the specified tests.
- Technicians are not aware of reference materials such as the Compliance Manual.
- Confusion arises in interpretation of the procedures, as the tests are complex and the forms are unclear.
- Contractor training is insufficient. Approximately half of the tests could not be performed without a moderate or substantial level of coaching.

6.2.3 Research Outcomes

Based on the findings from the two research elements of this task, the research team proposed changes for the 2013 Title 24 acceptance testing requirements. The revisions clarify test procedures and add references to additional resources, which will make it easier for testing contractors to conduct effective tests. The research team recommended that these changes be incorporated into the official Title 24 acceptance testing documentation to help improve compliance with these provisions. At the time of writing this report, the recommended documentation changes are under review.

Overall, this research illustrated that the success of the Title 24 acceptance requirements depends on a chain of responsibility linking design engineers, contractors, sub-contractors, owners and building officials. For each link in that chain to hold strong requires training on acceptance testing procedures and motivation to change the existing practices for contracting and code enforcement. Thus, a key outcome of this research was a set of specific recommendations for training and outreach to building officials, owners, engineering firms, and contractors.

6.3 Development of Outreach Materials

Based on the research findings, the research team developed 3 outreach documents, designed to help address barriers highlighted through the research. These documents are described below:

6.3.1 Acceptance Testing Bid Sheet[31]

One of the challenges highlighted through the project team's research was that some contractors who are aware of acceptance testing requirements fear that their competitors may offer reduced prices by omitting acceptance testing from their bids to owners. The Acceptance Testing Bid Sheet is designed to accompany a bid for services that include acceptance testing; this document describes acceptance testing requirements, explains that acceptance testing is mandatory, and describes the long term benefits of healthy and efficient buildings.

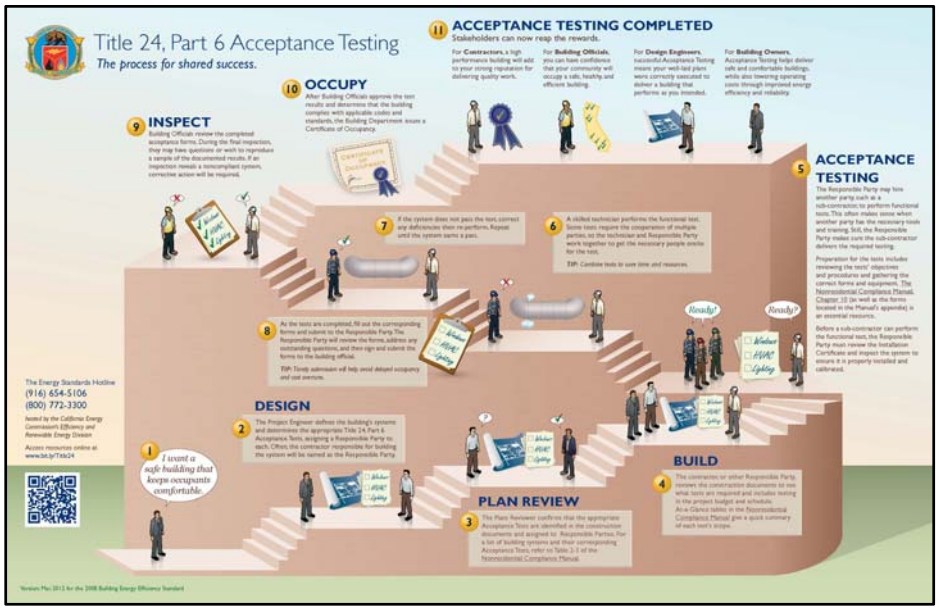
6.3.2 Acceptance Testing Infographic[32]

The Acceptance Testing process can be lengthy, complex, and involve many different parties. The project team's research indicated that often each party does not fully understand all of the required steps and how they are critical to the overall process. In response, the research team created an infographic describing each of the steps in the process, and highlighting the key documents and decision points (See Figure 7).

31 Available at http://www.cacx.org/resources/title24_acceptance_testing.html

32 Available at http://www.cacx.org/resources/title24/PIER_T24_Infographic.pdf

Figure 7: Infographic Describing the Steps for Performing Title 24, Part 6, Acceptance Testing



Source: California Commissioning Collaborative. © 2012

6.3.3 Contractor Case Study[33]

One of the barriers to effective acceptance testing is that performing these tests is typically a very small part of any contractor's work – as a result, contractors may not place much emphasis on ensuring that they are fully aware of testing requirements and on having all the necessary equipment. However, one of the contractors interviewed by the research team considered acceptance testing to be a core element of his business and was highly skilled in performing the tests. The research team determined that developing a case study with this contractor may be a useful tool in persuading other contractors to view expertise in performing acceptance tests as a selling point for their business. The resulting case study outlines this contractor's approach to acceptance testing, the challenges faced, and the benefits realized in terms of building performance and his own business success.

Each of the three outreach documents was branded with the Energy Commission logo. The research team considered it important that anyone viewing these documents considered them credible, and also that they would look to the Energy Commission if they had further questions or needed further resources. The Energy Commission already has a host of useful resources on its website, and the CCC wanted to encourage stakeholders to view the Energy Commission as the "go-to" place for anything related to Title 24.

6.4 Title 24 Acceptance Testing: Outreach

The task's research findings were presented in a poster presentation at the 2011 Behavior, Energy, and Climate Change (BECC) conference in Washington, D.C. Attendees discussed

33 Available at http://www.cacx.org/resources/title24/PIER-T24-Case-Study.pdf

research findings and identified barriers to success, and were asked to provide input on the proposed outreach materials and message. Their input helped shape the design and messaging of the outreach materials described above.

Each of the outreach documents was printed in volume:

- Infographic: 1,600
- Bid Sheet: 2,000
- Case Study: 1,400

Printed materials were distributed to the following organizations:

- Pacific Gas & Electric (PG&E), to share between all California Investor-Owned Utilities
- California Building Officials (CALBO)
- Contractors' State License Board (CSLB)
- Institute of Heating & Air Conditioning Industries, Inc. (IHACI)
- The Energy Commission
- California Commissioning Collaborative

Following a press release on March 7th, the Infographic, Case Study, and Bid Sheet were also reprinted by IHACI's Indoor Comfort News, which has over 100,000 visitors per month, and posted on the International Association of Plumbing and Mechanical Officials (IAPMO) website. CSLB also included the press release in their June newsletter, which is distributed to over 300,000 licensed contractors.

6.5 Title 24 Acceptance Testing: Conclusions and Next Steps

This project did not include any measurement of market impact from the research or the development of marketing materials. There are three key positive outcomes from the project that have been observed, however:

- The research report from this project was cited during public workshops considering the requirement that all acceptance testing be conducted by certified contractors.
- Outreach documents were distributed to the major organizations dealing with Title 24 compliance issues (and the CSLB also included the press release in their June newsletter).
- Obtaining Energy Commission approval for the outreach documents increased the credibility of the material among stakeholders.

The CCC has an ongoing relationship with the Energy Commission, through development of acceptance testing requirements, supporting documentation and training, and by presenting on Title 24-related topics at its meetings. The CCC will continue to support these efforts, and to promote the outreach materials developed under this project. In the short term, CCC will assist in updating Title 24 documentation for the upcoming code revision, and will consult with CCC staff on longer term needs.

CHAPTER 7:
Research Program Conclusions and Recommendations

The integrated R&D program *Building Commissioning: Strategies and Technologies for Energy Efficiency* met all of its goals. The program has resulted in the creation of major new resources that promote adoption of EBCx best practice – all of which are available free of charge for public use. These new resources are backed up with primary and secondary research that helped to shape the deliverables and also provides a basis for further work in the area of EBCx.

7.1 Program Conclusions

The tools and guidelines developed under this program directly contribute to the CPUC's Strategic Plan, goal 2-5-2: Strengthen Tools and Practices for Building Commissioning. The Strategic Plan calls to "develop tools and strategies to use information and behavioral strategies, commissioning, and training, to reduce energy consumption in commercial buildings." CCC's work under this PIER-funded R&D Program has been recognized in the Strategic Plan status update documents as providing leadership and progress in the building commissioning field. Specifically, the following deliverables help to address the Strategic Plan goal:

- The Facility Operations Assessment (FOA) toolkit
- ECAM, v2.0
- C-BOA
- The Building Performance Tracking Handbook
- The Guidelines for Verifying Savings from Commissioning Existing Buildings

In the absence of this PIER-funded program, it is highly unlikely that these freely-available tools and guidelines would have been developed. All of these resources promote EBCx best practice, and all except the FOA toolkit are intended to improve the cost-effectiveness of utility EBCx programs. Their release is timely, as 2013 will mark the start of a new utility program cycle, and the CCC will reach out to the utilities to support adoption of these new resources.

The CCC R&D management team coordinated the efforts of seven firms, with support from Technical Advisory Groups and the Program Advisory Committee comprising over 90 industry experts. In addition, the research teams engaged with numerous other industry experts and contractors in the course of their research, and outreach efforts placed program deliverables in front of tens of thousands of industry stakeholders.

In addition to PIER Program funding, this R&D benefited from an additional $120,000 of match funding from the CCC, the NEEA, and SCE. A significant portion of the program's funding was allocated to California-based firms, and the program outcomes are intended to directly contribute to increased employment of EBCx providers in California along with related industries such as the controls & mechanical contractors who implement EBCx measures.

7.2 Recommendations and Outstanding Research Needs

While the CCC is confident that the new resources developed under this program can help address barriers to greater market penetration of EBCx, it is too soon to assess their impacts (beyond counting downloads of documents and collecting user feedback); the CCC is uniquely positioned to support market adoption through its connections to EBCx program administrators and EBCx providers. CCC will continue to promote the newly-created resources long after the PIER funding period has ended, and will seek to continuously improve the tools and guidelines as needed, and as funds and other resources permit.

This R&D program is one in a series of phases that can take EBCx from a niche engineering specialty to 'business as usual.' Figure 8 illustrates a general progression of the EBCx industry, and indicates recommended next steps for supporting EBCx market growth.

Figure 8: EBCx Industry Progression

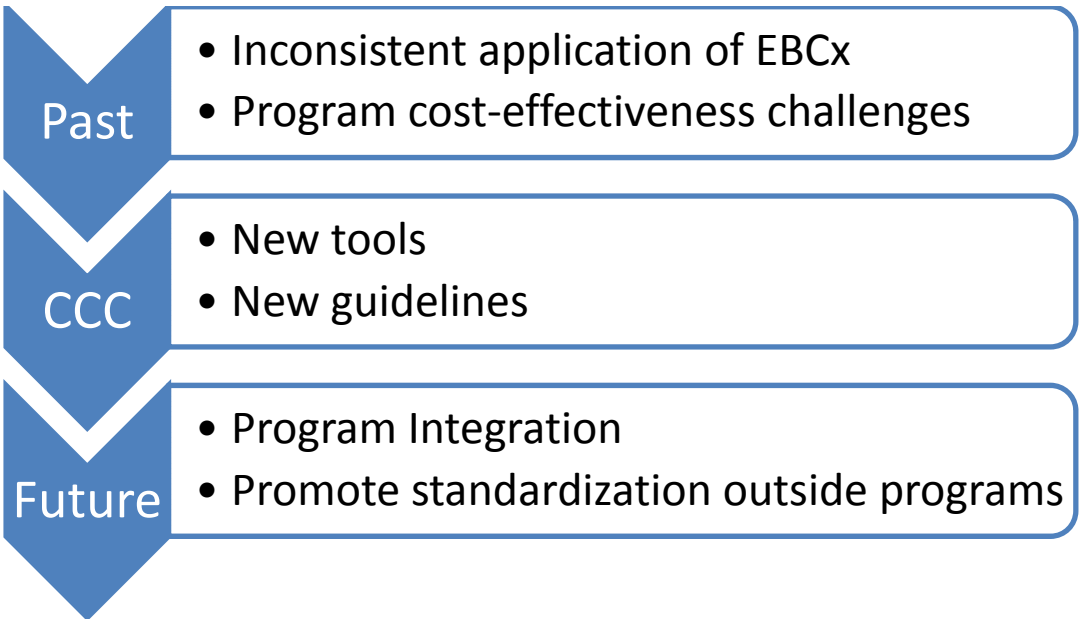


Figure 8 shows the past situation whereby EBCx was applied inconsistently between programs and providers, and utility programs faced severe cost-effectiveness challenges in managing that inconsistency. This PIER-funded R&D project has developed tools and guidelines that are intended to help address these challenges. The R&D team's recommended future steps include program integration and promoting standardization of EBCx.

7.2.1 Energy Efficiency Program Integration

Tools and guidelines will not impact the market by themselves. The R&D team conducted a range of successful outreach activities under this program, and further activities are recommended to ensure the benefits of these tools and guidelines are fully realized:

- **Encourage adoption of new tools and guidelines by providers and program managers:** CCC will continue working with utility program managers and EBCx providers to promote adoption of the tools and guidelines developed under this program. In parallel with promoting adoption, gathering feedback on the effectiveness of these new resources will help facilitate continuous improvement.
- **Develop programmatic approaches with integrated building performance tracking tools:** Advanced monitoring systems show great potential for supporting programs with recruitment, identifying measures, quantifying savings, and increasing persistence of savings. In each of these areas there are a series of specific research questions to address, as described in Chapter 4.
- **Support whole building approaches capturing retrofit, operational, and behavioral savings.** Related to the bullet above, the CCC's work on monitoring systems and in developing the new verification of savings guidelines has contributed to an industry-wide collaborative effort towards taking whole building programmatic approaches. Creating whole building approaches will require further data analysis research and an unprecedented level of collaboration between utilities, the CPUC, software vendors, EBCx providers, and other industry groups.
- **Incorporate tools and guidelines into the Energy Commission's Comprehensive Energy Efficiency Program for Existing Buildings (AB 758):** The Energy Commission's Comprehensive Energy Efficiency Program for Existing Buildings is targeting improved energy efficiency for California's existing buildings through all possible means. The resources developed under this R&D program can be valuable for incorporating EBCx as a key element of the AB 758 Program. CCC staff will continue working with Energy Commission staff to identify integration opportunities.

The start of the California utilities' "transition" program cycle in 2013 provides a timely opportunity to increase quality and consistency of EBCx projects in California through adoption of the CCC's tools and guidelines, in time for the start of the next full program cycle in 2015.

7.2.2 Standardization of EBCx Outside of Programs

Improving the cost-effectiveness of existing utility EBCx programs was one of the stated goals of this R&D program, but the ultimate goal is market transformation: creating market conditions whereby EBCx is business as usual, in the absence of utility incentives. To move towards market transformation, the R&D team has the following recommendations:

- **Clarify the EBCx business case for building owners & managers, and develop financial decision-making tools to support EBCx investments:** Awareness of EBCx has increased significantly over the past decade among building owners and managers, but it is believed that market penetration is still very low, especially in the absence of utility incentive programs. Research indicating median savings of 16 percent with a simple payback of 1.1 years makes a compelling case for EBCx projects, but owners' investment decisions are seldom made based solely on savings percentage and simple payback. There is a need for research into building owners' investment processes and metrics,

performance of EBCx against those metrics, and development of tools that can help make the business case for EBCx in a clear and transparent manner.

- **Engage market stakeholders in the property valuation community to promote operational assessments at time of sale:** The FOA toolkit provides a new tool for time-of-sale application. It is recommended to conduct further research into the benefits of this process and to hone the toolkit through larger scale pilots. The FOA is built around EBCx, but it is recommended that follow up research considers a broader view encompassing retrofit opportunities also.
- **Develop EBCx approaches for hard-to-reach building/owner types:** Cost-effective EBCx programs for buildings smaller than 100,000 square feet are not yet established; multi-tenant properties with a complex ownership structure are another property type that have presented challenges for EBCx approaches. The R&D team recommends performing a market assessment for these underserved market sectors, to determine the property/owner characteristics, determine the key barriers for EBCx, and define the size of the market opportunity. This research could then stimulate the design of programmatic pilots for the utilities' transition period, leading to scaled up programs for the 2015 program cycle. The initial market research phase could overlap with research into application of monitoring systems and whole-building approaches noted earlier, as these options may significantly improve EBCx cost-effectiveness.
- **Collaborate with influential industry organizations within California:** In order to achieve market transformation, two key conditions are required:
    - Mature EBCx delivery infrastructure, whereby EBCx providers, controls contractors, and mechanical contractors have the marketing skills and the motivation to secure EBCx project work on a short sales cycle and in the absence of utility program marketing efforts.
    - High market demand, whereby property owners and managers choose to perform EBCx based on 'business as usual' practice, supported by established cost effectiveness metrics and investment processes.

Moving towards market transformation for EBCx would require collaboration between influential industry groups – organizations such as BOMA, the International Facility Management Association (IFMA), and the California Chapter of the Building Commissioning Association (BCA). The evolution of utility EBCx programs to date has largely been driven by regulatory, cost-effectiveness, and program management-related factors – moving to a market-driven approach will involve different considerations and financial metrics, and so it will be important to involve the relevant stakeholders in taking leadership.

GLOSSARY

Acronym	Definition
AB 1103	California State Assembly Bill 1103: Commercial Building Energy Use Disclosure Program
AB 758	California State Assembly Bill 758: Comprehensive Energy Efficiency Program for Existing Buildings
BAS	Building Automation System
BCA	Building Commissioning Association
BOA	Building Optimization Analysis tool
BOMA	Building Owners and Managers Association
C-BOA	Custom Building Optimization Analysis tool
CCC	California Commissioning Collaborative
CPUC	California Public Utilities Commission
CRE	Commercial real estate
Cx	Commissioning
EBCx	Existing building commissioning
ECAM	Energy Charting and Metrics
Energy Commission	California Energy Commission
FOA	Facility Operations Assessment
HVAC	Heating, ventilating and air conditioning
IFMA	International Facility Management Association
IPMVP	International Performance Measurement and Verification Protocol
kWh	Kilowatt-hours
LBNL	Lawrence Berkeley National Laboratory
LEED	USGBC's Leadership in Energy and Environmental Design Certification Program
M&V	Measurement and verification
NBI	New Buildings Institute
NEEA	Northwest Energy Efficiency Alliance

Acronym	Definition
PAC	Project Advisory Committee
PCA	Property condition assessment
PECI	Portland Energy Conservation, Inc.
PIER	Public Interest Energy Research Program
PNNL	Pacific Northwest National Lab
QuEST	Quantum Energy Services & Technologies, Inc.
RCx	Retrocommissioning
R&D	Research & Development
RD&D	Research development and demonstration
TAG	Technical Advisory Group
UCA	Utility Consumption Analysis
USGBC	United States Green Building Council
VFD	Variable Frequency Drive
VoS	Verification of Savings